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STABLE DEFENCE

FINAL REPORT

Panel 7 on the Defence Applications of Operational Research

Research Study Group 18 on Stable Defence

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14. Abstract:

The study addresses the implication of conventional military forces for regional stability, in particular under conditions of multipolarity. The study formulates a definition of military stability that integrates intention, risk aversion, military power, and the security need of each party within the region. The study develops a mathematical framework for analysing stability. It is used to evaluate notional conflict situations and to provide first order estimates ond efensive military deficits in order to establish a stable multipolar region. In addition, the properties of military posture that might be conductive to stability are addressed by formulation of a set of explicit hypotheses. A subset of these is tested using computer simulation experiments.

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DEFENCE RESEARCH GROUP

PANEL 7 ON THE DEFENCE APPLICATIONS OF OPERATIONAL RESEARCH

RESEARCH STUDY GROUP 18 ON STABLE DEFENCE

Technical Report on Stable Defence

1. This is the Technical Report on Stable Defence - Final Report - prepared by the Research Study Group 18 on Stable Defence under Panel 7 on the Defence Aplications of Operational Research.

2. The Executive Summary ("Yellow Pages") of this report has been issued under reference AC/243-N/410, dated 5 April 1995.

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EXECUTIVE SUMMARY

INTRODUCTION

i. The transformation of Europe from a relatively simple bipolar system to a complex, multipolar one has resulted in a new international security situation. The bipolar system turned out to be fairly peaceful for more than four decades. However, this peace was expensive because it involved extensive unilateral adjustments of military forces. The adjustments led to an arms race where military spending by one side resulted in further military spending by the other side. After the implementation of the CFE Treaty, the bipolar situation was characterised by approximate parity at a lower level of the principal conventional weapon system categories between NATO and the former WTO. Parity contributed to stability. The disintegration of the Soviet Union and the WTO has made parity between the former groupings an obsolete measure of military stability. Now the military situation in Europe is characterised by a number of regions, each of which may be a multipolar system. Obviously, the new situation is neither peaceful nor stable.

ii. The new environment poses a number of important questions for stability. The purpose of this report is to contribute to the development of sound answers to these questions. It is recognised that military factors are only one, although a major, influence on stability. Stability is affected by many other factors such as the political, historical, social, cultural, geographic, and economic characteristics of the region. This report, however, addresses the implications of conventional military forces for regional stability, in particular under conditions of multipolarity.

iii. Multipolar military stability is influenced not only by equipment and manpower but also by other factors such as doctrine and operational concepts. Leadership, training and morale are also of great importance. An evaluation of the likely outcome of military conflicts is an essential part of stability analyses. For perfect military stability, each party must possess a defensive capability sufficient to deter any hostile party from an attack, or to repel an aggressor if attacked. The relationship between offensive and defensive capabilities is thus instrumental for stability.

iv. A suitable conceptual framework is fundamental for analysing stability. Furthermore, a mathematical model based on this framework makes it possible to study the relations between relevant military factors and to provide quantitative measures for the degree of stability. Such a model can be used to evaluate the current situation and to estimate any deficit in defensive combat power of the parties that needs to be eliminated in order to establish stability.

GENERAL APPROACH

v. Panel 7 established RSG.18 on Stable Defence at its January 1992 meeting. The Terms of Reference of RSG.18 identified two major tasks. The first one relates to an analytical approach to describe military stability. The RSG should look for methods and models to study how to achieve a stable military situation in a multipolar context. To this end, the RSG should first survey literature and analytical models relevant to stable defence. Secondly, the RSG should develop an analytical framework for assessing the fundamental requirements for and constraints on military forces to ensure a stable defence in a multipolar context. As an integral part of this process the RSG should formulate measures of stability. The second task concerns generic structures and scenarios of relevance to the European situation. The RSG should, if possible, produce a list of military factors that might enhance military stability. The RSG should then define and perform combat simulation experiments for testing hypotheses concerning the factors on the list. The RSG.18 formulated a programme of work for addressing these tasks within a two year period.

MILITARY STABILITY

vi. RSG.18 has formulated a definition of stable defence. A party has established a *unilateral stable defence* against the other parties within a region if the party is confident that: the other parties have no intention of launching an attack, or the other parties cannot accept the risk of attacking, or any attack can be repelled. If all parties within a region have established a unilateral stable defence, the region is a *multipolar stable defence system.*

vii. This definition considers the nature of non-military relations between the respective party and its potential adversary, the adversary's presumed military risk attitude, the combat outcome in case on an aggression, and the party's security needs. The non-military relations reflect a web of historical, cultural, ethnic, economical and other ties. If they are friendly, the adversary will not consider military aggression as a means of resolving eventual conflicts. Therefore, the party has no need for a military defence against the adversary. However, even if non-military relations are less than friendly, or outright hostile, it is not certain that the adversary will attack. Whether or not he does depends on his military risk attitude with a view to the likely combat outcome. The combat outcome depends on many factors, the adversary's offensive and the party's defensive military capabilities among them, and cannot be predicted with certainty. Finally, the security needs of a party are satisfied if the party feels confident that it does have a unilateral stable defence. The degree of confidence, i.e., the degree of military stability a party requires, reflect the residual risk it sees fit to accept. Thus, it is important to note that military stability is not an objective concept. The intentions of other parties, their military risk attitudes and, to some degree, the evaluation of the outcome of aggressions as well as the security need are all based on subjective judgements.

viii. In the sense that a party feels confident about its security, this definition implies what may be called the *confidence view* on unilateral military stability. However, as there is no way in which intentions and risk attitudes of other parties may be assessed with certainty, two different views are presented which imply special cases of the confidence view. The *sufficiency view* does not require an assessment of intentions the adversaries. Rather, it infers that the security needs of a party are satisfied if the adversaries are regarded as risk averse in the sense that they are not willing to accept the risk associated with launching an attack. The other view, the *security view*, is based on the defence capability of the party and leaves out both the intentions and the risk aversions of the adversaries. The party considers the situation as stable if the probability of repelling an attack exceeds the required security level. The security view does not require any assessment of the intention and risk aversion of adversaries. It only considers the military capabilities and the probability of a successful defence. The three views on stability lead to different defence force requirements. The force levels at which the security needs can be satisfied are the lowest for the confidence view and the highest for the security view. The sufficiency view represents an intermediate stability attitude.

MATHEMATICAL FRAMEWORK

ix. The RSG has developed a mathematical framework for analysing stability that inter-relates intentions, risk aversion, and military power. This framework integrates the use of multiple dissimilar models, and combines static and dynamic approaches. In particular, the so-called *stable regional force ratio* concept provides a rather simple, yet comprehensive, approach for addressing a number of factors essential to a party's offensive and defensive capabilities vis-à-vis other parties. It was used to evaluate notional conflict situations and to provide first order estimates on defensive deficits in a region and on options to eliminate them in order to establish a stable multipolar system.

MILITARY FACTORS INFLUENCING MILITARY STABILITY

x. The properties of a military posture that might be most conducive to stability are addressed by a set of explicit hypotheses. This serves several purposes. First, an explicit catalogue of hypotheses illustrates the breadth and complexity of the military issues associated with stability. Second, such a list provides a research agenda to encourage further investigation. A complete understanding of such a complex problem will require an accumulation of insights by multiple researchers over a considerable period of time. Third, such a list should facilitate the development of policy recommendations even before the growth of knowledge yields complete understanding. Finally, and perhaps most important for purposes of RSG.18, an explicit list of hypotheses may facilitate simulation analysis by identifying a discrete set of questions for the simulations to address.

xi. The set of more than 70 hypotheses on military stability developed by the RSG may be grouped into six broad categories:

- *Strategic factors* relevant to military stability include strategic conceptions and resulting military doctrines; scientific, industrial, and economic capabilities; terrain and militarily relevant infrastructure; mobilization capabilities and postures; and force ratios.

- *General military factors* relevant to military stability include training and morale; force readiness; logistic posture; command, control and communications capabilities; and intelligence collection, target acquisition and surveillance capabilities

- *Force components* relevant to military stability include armor; infantry; artillery; counter-mobility capabilities; obstacle breaching and crossing capabilities; air defense; air mobility and mechanization of land forces; battlefield ground attack air capabilities; offensive counter-air capabilities; deep interdiction capabilities; and defensive counter-air capabilities.

- *Factors specific to certain parties* and relevant to military stability include maritime power projection capabilities; amphibious capabilities; and special operations capabilities.

- *Properties of the international system* relevant to military stability include its polarity and the patterns of alignment among states.

- *Properties of domestic political, economic, or social structures* relevant to military stability include the nature of governing regimes, or civil-military relations within states.

APPROACH AND MOTIVATION

xii. The RSG's work seeks to bring into the NATO debate on conventional warfare some new thinking on what forms of stability the international community should pursue. Previously security was thought of mainly in terms of a perilous balance. Many were concerned that this balance could be upset too easily by military build-ups in peacetime, or by precipitous escalation in crisis. The RSG has envisaged a situation where the international security situation is such that the possibility of successful aggression by any party is minimised. The RSG has taken the first step to look at this, and the RSG hopes to raise awareness within the analytical community of the possibility of achieving more stable relationship between nations. The RSG has considered the influence of a regional collective defence or security organisation and the influence that the international community may have on regional stability through an international force.

xiii. The RSG's work has laid down a foundation for attacking problems of military-political nature, which was largely absent from previous DRG sponsored studies. The RSG has shown how an analytical approach to this type of problem is possible.

xiv. It should be noted that, within the time and resources available to RSG.18, analysis and hypothesis testing could not be exhaustive and was limited to selected scenarios that were compatible with the models and experiments that the participating nations were ready to contribute. Nevertheless, the results obtained are judged to be significant and to provide a sufficient basis for drawing some substantial conclusions.

xv. The experiments conducted by RSG.18 involved five models: four combat simulation models for testing tactical level stability hypotheses, and one analytical equilibrium model for testing hypotheses on regional ground and air force balances. The latter model (SRFR) was contributed by Germany, the simulation models were contributed by Denmark (SUBSIM), Germany (KOSMOS and TRIAMOS), and the United States (JANUS).

GENERAL CONCLUSIONS

xvi. The RSG's model analysis suggests that the risk attitudes of the parties have a powerful influence on stability. In particular, if the parties assess other, potentially hostile, parties as highly risk averse, and are willing to accept some degree of risk themselves, then stability can be obtained at modest force levels, and without extensive force re-structuring. If, however, the opposite risk attitudes prevail, that is, if the parties assess other parties as not very risk averse, and insist on very high confidence that their own defences will hold if tested, then the result is instability almost regardless of plausible force levels or equipment types.

xvii. This conclusion stems in part from the RSG's finding that purely defensive[1] forces are rather infeasible, at least within the foreseeable future. If feasible and cost-effective purely defensive forces could be identified, then stability could be obtained at plausible force

[1] Purely defensive, reactive, or non-offensive defence (NOD) systems are all terms used for systems which only can be used for strictly defensive purposes.

levels regardless of the parties' risk preferences. The RSG's simulation experiments, however, failed to provide any evidence that such purely defensive forces could be created.

xviii. The absence of purely defensive forces makes it impossible to compensate unilaterally for imbalances in the military capabilities of individual states in a multipolar international system. To the extent that purely defensive forces cannot be identified, it therefore follows that it would never be possible to escape the security dilemma: that is, the problem of neighbours interpreting defensive improvements as threatening.

xix. This implies that some external assistance to defenders would be required to ensure stability. This external assistance could take the form of collective defence arrangements, international military forces, ad-hoc coalitions, or some combinations of these. Of course the nature, charter, or membership of such organisations was beyond the scope of the RSG's analysis; nonetheless the results obtained point to the necessity of some such means if a high degree of multipolar stability is to be attained.

xx. While the creation of collective defence or security arrangements capable of matching aggressive armies with superior force would in theory provide such means of compensation, the nature, charter or membership of such an organisation is beyond the scope of the RSG. An organisation can contribute to security enhancement while alleviating the security dilemma through appropriate organisational means, such as a transnational composition of military units and a multinational division of labour, which may make offensive operations difficult without the unanimous agreement of all parties.

xxi. Operational concepts and doctrine also have a major effect on stability. In particular, shallow, passive defensive doctrines make successful defence extremely difficult over a wide range of force ratios or equipment types, and are highly destabilizing. On the other hand, a mobile defence in some depth having the capability for quick counter-concentration is rather stable in comparison to a static forward defence.

xxii. However, unless counter-concentrations can be effected by highly accurate long-range fire, they necessitate a high degree of operational mobility for the defender forces in order for stability to obtain. This may give rise to perceptions of offensive intent. Yet, if all parties in a region dispose their forces in this manner, there is no reason to believe that this will increase the ability of any one to attack any of the others. Moreover, if all parties in a region are given faster transportation systems there is again no reason to believe that this will on balance increase the capability of attackers more than the capability of defenders.

xxiii. Offensive air capabilities tend to be destabilizing unless compensated by air defenses capable of protecting offensive air systems against air strikes, thus removing a pre-emption bonus, and capable of neutralizing them when they attack land force assets and communication lines of the defender only. Thus, in order to favour the defending side air defenses should be either stationary or have mobility limitations designed into them so that they may not provide protection for ground forces advancing rapidly on enemy territory.

SPECIFIC CONCLUSIONS

xxiv. With a few exceptions, the simulation experiments conducted by RSG.18 for testing stability hypotheses featured break-through battles on divisional or lower levels. It should be noted that the hypotheses could be tested in a few scenarios only. Nevertheless, the results obtained have been significant and are sufficient to draw the following conclusions.

xxv. The simulation experiments were conducted in four sets, using four national models: a test of hypotheses regarding the stability properties of infantry using the U.S. Janus model; a test of hypotheses regarding the stability properties of decoys using the Danish SUBSIM model; a test of hypotheses regarding the stability properties of air mobility using the German TRIAMOS model; and tests of several hypotheses regarding the stability properties of tanks, artillery, force levels, tactical doctrine, and terrain using the German KOSMOS model. Altogether, hypotheses testing involved more than 350 different combat situations. The number of simulation runs exceeded 17000.

xxvi. In the evaluation of the experiments all options favouring the defender more than the attacker are assumed to have stabilizing effects, and vice versa. If several options are available, the optimal one for the attacker is the most destabilizing one, and for the defender the most stabilizing one.

xxvii. There are no type of *combat units* among those investigated that are purely defensive or offensive. In particular, the analyses conducted failed to sustain the hypotheses that infantry is stabilizing and armour is destabilizing. There is no evidence that tank-heavy formations significantly favour the aggressor while infantry-heavy formations favour the defender. The extent to which any of the investigated combat units performs better in defensive than in offensive operations, or vice versa, depends on the prevailing situational parameters (terrain, visibility, combat mode, degree of defense preparation, etc.)

xxviii. Even in modern warfare, *infantry* seems to be quite capable of offensive operations when visibility is poor and/or terrain is rough. In that case, the probability of accomplishing a successful break-through is higher for infantry-heavy forces than for tank-heavy forces. A break-through is virtually certain if the defender has no time to prepare positions (deliberate defense).

xxix. *Tanks* represent a formidable defensive system, especially when visibility is good and terrain favourable to armoured operations. In fact, a comparison of the experiments involving tank-heavy and infantry-heavy forces on both sides indicates that a defender benefits more than an attacker from adding tanks to his force.

xxx. In addition to situational conditions, the stabilizing effects of *artillery* depend primarily on whether or not there is a defense advantage in the sense that defender units are less susceptible to artillery effects than attacker units because of concealment and cover. In that case, artillery tends to be stabilizing. However, whether this remains true if smart artillery munitions are available rather than the HE-munitions used in the experiments needs to be investigated.

xxxi. The contributions of *helicopters* to stability depends significantly on the availability of *air defense*. Similar to artillery, attack or anti-tank helicopters contribute to stability only if there is a significant advantage for the defending side from concealment and cover of targets as well as from air defense. Thus, highly mobile short-range air defenses favour the attacker more than the defender. In contrast, non-mobile long-range air defense systems that cannot escort armour, but have sufficient range to cover the area of defense operations, are stabilizing.

xxxii. In many experiments, *mines* deployable by rocket artillery have favoured the attacker more than the defender. This was because they delay the movement of the defender's reserves. Thus, the reserves were not available in time to be of any significant benefit to the defender. Although the second echelon of the attacker was delayed as well, the lack of reserves is more detrimental to defense operations than the lack of the second echelon forces to attack operations. Even though available as an option in the simulation models, conventional laying of mines by engineers was not observed in any of the experiments. This is because the time requirements for the conventional deployment always exceeded the time available for defense preparations during the battle. Thus, in order to contribute to stability, mines must be deployed early as part of the initial defense preparations in anticipation of an attack.

xxxiii. The use of *decoys* increases the military capability for the defender and the attacker. The defender and the attacker may gain equally from employment of decoys. However, the ability to deploy decoys may differ for the defender and the attacker. A defense from prepared positions will provide the best possibility to insert decoys in a way that resembles to real units. This possibility is not always available to the attacker. The great advantage of deploying decoys and the greater possibility for the defender to do so shows that the use of decoys is advantageous to the defense. In this way, decoys will have at least a marginal enhancing effect on stability.

xxxiv. On a *thinned-out battlefield* the capability for an immediate response of the defender to enemy actions is extremely important for stability, i.e., time and place of attacks must be anticipated in time so the defender does reach prepared positions before the attacker arrives there. In other words, for a stable defense under thinned-out battlefield conditions real-time reconnaissance, high mobility, and the means to delay and canalize attacks are indispensable.

xxxv. In all experiments, a certain defense advantage was assumed to exist. Thus, the longer a battle lasts the more the defender may benefit from this advantage. Therefore, decreasing the *attack velocity* on the tactical level contributes to stability.

xxxvi. The experiments of RSG.18 indicate that *visibility* is not a major factor affecting armoured battles. However, the more infantry is involved the more critical a factor visibility becomes. Poor visibility conditions are highly essential for the success of infantry attacks. A deliberate armoured defense stands almost no chance to prevail when attacked by infantry when visibility is poor. However, when attacked by armour, poor visibility benefits an infantry-heavy defender more than the attacker.

RESERVATIONS

xxxvii. Finally, it should be re-emphasised that the military influence on stability is only one factor amongst many, although it is a major one. The very important non-military issues of stability are a result of many factors that depend on particular historical, social, cultural, economic, etc., conditions of each party in the region, and in particular the differences between the parties with respect to these factors. Moreover, the outcome of a military conflict is not determined only by equipment and manpower but is also strongly affected by other factors such as leadership, training, morale, although these factors could not be incorporated explicitly into the analysis.

RECOMMENDATIONS

xxxviii. The inability to overcome the security dilemma and provide stability through purely defensive military systems or force design constitutes an important motivation for more careful study of the potential of regional collective security.

xxxix. Likewise, options for effective international forces to provide the necessary military capability for a stable regional defence system warrant further study as a matter of priority. This should include consideration of the crisis management system within which this force would be intended to operate. It would be useful to continue and expand the experimental research initiated by RSG.18 on a collaborative basis to aid the design of military forces that would implement any of the various options.

xl. The importance of doctrinal choices for stability suggests the potential importance of doctrinal interchange between nations as means of ensuring that sound defensive doctrines are adopted as widely as possible. Therefore, international doctrinal collaboration in the interests of more effective defensive force employment should be encouraged and expanded.

xli. Of course the conclusions reached here necessarily depend on a partial set of hypotheses tests. While the RSG feels that the tests conducted represent a reasonable basis for reaching its conclusions, national analysis establishments are invited to complement the RSG's work, in particular in the areas of hypotheses testing and scoring systems validation.

OUTLINE OF CHAPTERS

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

1. The transformation of Europe from a relatively simple bipolar system to a complex, multipolar one has resulted in a new international security situation. The bipolar system turned out to be fairly peaceful for more than four decades. However, this peace was expensive because it involved extensive unilateral adjustments of military forces. The adjustments led to an arms race where military spending by one side resulted in further military spending by the other side. After the implementation of the CFE Treaty, the bipolar situation was characterised by approximate parity at a lower level of the principal conventional weapon system categories between NATO and the former WTO. Parity contributed to stability. The disintegration of the Soviet Union and the WTO has made parity between the former groupings an obsolete measure of military stability. Now the military situation in Europe is characterised by a number of regions, each of which may be a multipolar system. Obviously, the new situation is neither peaceful nor stable.

2. The new environment poses a number of important questions for stability. The purpose of this report is to contribute to the development of sound answers to these questions. It is recognised that military factors are only one, although a major, influence on stability. Stability is affected by many other factors such as the political, historical, social, cultural, geographic, and economic characteristics of the region. This report, however, addresses the implications of conventional military forces for regional stability - and in particular, under conditions of multipolarity.

3. Multipolar military stability is influenced not only by equipment and manpower but also by other factors such as doctrine and operational concepts. Leadership, training and morale are also of great importance. An evaluation of the likely outcome of a military conflict is an essential part of stability analyses. For perfect military stability, each party must possess a defensive capability sufficient to deter any hostile party from an attack, or to repel an aggressor if attacked. The relationship between offensive and defensive capabilities is thus instrumental for stability.

4. A suitable conceptual framework is fundamental for analysing stability. Furthermore, a mathematical model based on this framework makes it possible to study the relations between relevant military factors and to provide quantitative measures for the degree

of stability. Such a model can be used to evaluate the current situation and to estimate any deficit in defensive combat power for the parties in order to establish stability.

1.2 TERMS OF REFERENCE

5. Panel 7 established an Exploratory Group (EG) at its meeting in June 1990. The EG was tasked to assess interest among NATO countries to undertake the proposed study on stable defence and to determine the possible contributions that each nation could make to such a study. The EG was further tasked to prepare recommendations for a study. The EG met twice, once in December 1990 at DDRE in Copenhagen and again in April 1991 at IABG in Munich. At the second meeting Terms of Reference (TOR) and Programme of Work (POW) were produced for the study and subsequently briefed to Panel 7. After some minor changes the Terms of Reference were accepted by Panel 7 and the Defence Research Group. The Terms of Reference identify two major tasks.

- The first task relates to an analytical approach to describe military stability. The RSG should look for methods and models to study how to achieve a stable military situation in a multipolar context. To this end, the RSG should first survey literature and analytical models relevant to stable defence. Secondly, the RSG should develop an analytical framework for assessing the fundamental requirements for and constraints on military forces to ensure a stable defence in a multipolar context. As an integral part of this process the RSG should formulate measures of stability.

- The second task concerns generic structures and scenarios of relevance to the European situation. The RSG should, if possible, produce a list of military factors that might enhance military stability. The RSG should then define and perform combat simulation experiments for testing hypotheses concerning the factors on the list.

6. The Terms of Reference are shown in their entirety in Annex I.

1.3 GENERAL APPROACH

7. Panel 7 approved the proposed study at its January 1992 meeting and RSG.18 on Stable Defence was set up. Denmark accepted the chairmanship of the RSG:

8. The first meeting of RSG.18 was held in May 1992 in NATO Headquarters. The RSG included participants from Canada, Denmark, France, Germany, Greece, the Netherlands, UK, US, Turkey, International Military Staff and SHAPE Technical Centre. At

the first meeting the UK representative was elected secretary. It was decided that the secretary should only produce a record of the actions and decisions of the meetings. At the first meeting the terms of reference were reviewed and the way ahead worked out. The RSG.18 formulated a programme of work for a two year period to be conducted in a number of parallel activities as follows:

- Conduct a survey of literature and national studies relevant to stable defence that could be made available to RSG.18.
- Develop a definition of military stability.
- Develop an analytical framework for analysing military stability in a bipolar and multipolar context.
- Identify military factors which might influence military stability.
- Evaluate these factors by appropriate simulation experiments conducted by the participating nations.
- Prepare the final report.

9. The Programme of Work is shown in Annex II.

10. The RSG held five ordinary meetings and one subgroup meeting. The first meeting was held in May 1992 in NATO Headquarters. The second meeting was held at Industrieanlagen-Betriebsgesellschaft mbH (IABG), Munich in October 1992. After this meeting Turkey did not participate further. The third meeting was held at National Defence Headquarters, Ottawa in May 1993. The fourth meeting was held at Defence Planning and Programming Directorate (ΔΑΣΠ), Athens in November 1993. The fifth meeting was held at Danish Defence Research Establishment, Copenhagen in March 1994. A special subgroup meeting on infantry modelling was held at the Institute for Defense Analyses, Virginia in late March and the beginning of April 1993. After this meeting the Netherlands withdrew their participation due to budget limitations.

1.4 STRUCTURE OF REPORT

11. Chapter 2 presents a conceptual definition of military stability. Chapter 3 develops a mathematical model of military stability, assuming independence of parties (this assumption is relaxed in Annex V). Chapter 4 produces a catalogue of hypotheses regarding military factors presumed to influence stability. Chapter 5 describes the tests of hypotheses concerning military stability. Chapter 6 presents an illustrative assessment of regional

multipolar stability based on the concept of the Stable Regional Force Ratio. Results, conclusions and recommendations are given in Chapter 7.

12. Background material and detailed discussions of particular subjects are included in the annexes. The first two annexes present the terms of reference and programme of work. Annex III on "Non-Military Factors Impacting To Regional Stability" describes a model to assess the conflict potential of a geopolitical region. Apart from two military indicators there are seven non-military criteria included in the model that can influence not only the start of a crisis, but also the progress of a military conflict. In Annex IV, a description of each of the national models used in the simulation experiments and the results obtained are given. Annex V derives a detailed mathematical model of multipolar stability for a many-on-one situation without the simplifying assumption with regard to independence between the actions of the parties Annex VI presents a review of some scoring systems to provide index measures for estimating the combat potential of heterogeneous military forces and, in particular describes the APP (anti-potential potential) method. Annex VII provides glossary of terms and acronyms, and Annex VIII presents references to papers produced in the RSG and other recent literature of relevance for military stability considerations.

CHAPTER 2

CONCEPTUAL DEFINITION OF MILITARY STABILITY

2.1 GENERAL

13. A multipolar system includes a number of parties. Usually the multipolar system is a specific geographical region with parties defined as countries or military alliances between countries associated with the region. The parties may have military out-of-region obligations, and they may be more or less friendly or hostile to each other. Usually, each party requires some military capability.

14. A party has a *unilateral stable defence* within the region, if the party is confident in relation to all other parties within the region. This is achieved if the party does not consider any other party to have hostile intentions, or if the other parties are considered unwilling to take the risk of launching an attack, or if the party in case of attack considers to have a sufficient military defence to repel the attack.

15. If each party within the region has established a unilateral stable defence, the region is named a *multipolar stable defence system.*

16. Stable defence depends among other factors on the *military capabilities* of the parties involved. If a party increases its military capability, for offensive or defensive purposes, other parties might feel threatened and increase their military capability as well, and consequently the first party might be threatened to a further increase of its military capability. In this way an arms race has often been initiated.

17. The military forces of a party provide *a defensive and an offensive military capability*. If a party is able to increase the defensive military capability without simultaneously increasing the offensive military capability this will enhance its own stability without threatening any other party. Another and less expensive way to stability might be to convince the other parties to reduce their offensive capabilities or to establish defence treaties. In all cases an arms race might be avoided.

18. An interesting and most relevant option with regard to establishing a multipolar stable defence system within a region might be the formation of an international force with the sole purpose to reinforce the defensive military capability of any party if necessary. An international force used this way improves multipolar stability.

19. With most traditional military forces there is a strong positive correlation between the defensive and the offensive military capability of the party. But the defensive military capability will usually be larger the offensive military capability, and this feature alone will in many cases make it possible to implement a multipolar defence system.

20. Furthermore it might be possible to identify or develop military means with a considerable higher defensive than offensive military capability. By deliberate use of such means it may be possible to facilitate multipolar stable defence systems.

21. Finally it is important to notice that military stability is not an objective concept. The intentions of other parties, the risk aversions of other parties and, to some degree, the evaluations of the outcome of aggressions are all based on subjective judgements. This might cause disagreement between the parties involved with regard to the requirements to a multipolar stable defence system.

2.2 UNILATERAL STABILITY

2.2.1 Conceptual model for unilateral stable defence in a bipolar situation

22. A simple situation with a region consisting of only two parties is investigated. The security and defence issues of one *party* with respect to the other party, the *adversary*, are examined.

23. The party considers its defence and security prospects regarding the adversary within a specified time horizon, e.g., the next 15 years. For simplicity, it is assumed that no changes that will influence the relationship between the party and the adversary will take place within this time horizon.

24. Four different aspects are considered by the party. These will be discussed in detail below:

- intentions of the adversary
- risk aversion of the adversary, if attack is considered
- combat outcome in case of an attack
- security need of the party

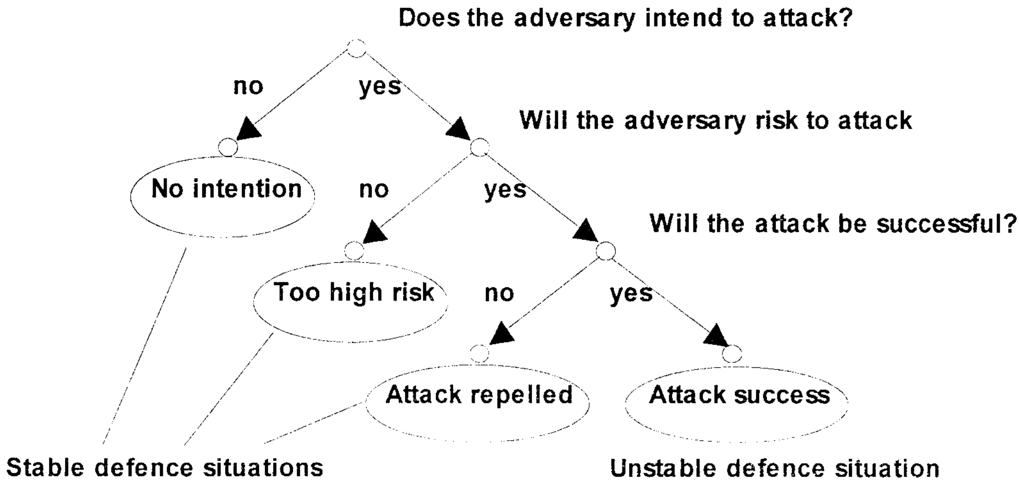

FIGURE 2.1 Stability aspects of a party with respect to an adversary

25. The **intentions of the adversary** concern the non-military relationship between the party and the adversary based on historical, cultural, ethnic, economical, etc., factors. If the relationship between the party and the adversary is friendly, the adversary will not consider military aggression and the party will have no need for a military defence against the adversary. If on the contrary the relationship is hostile, the adversary may want to attack, and the party may need a military defence against the adversary. Unfortunately the intentions of the adversary are subjective to the adversary and only known with certainty by the adversary. The party has no way to know for certain what they really are. The party is forced to make his own subjective evaluation of the adversary's intentions. It may be correct or it may be erroneous. Nevertheless, this evaluation is unavoidable and will influence the military capability that the party considers necessary.

26. The **risk aversion of the adversary** is the next aspect to consider. Even if the adversary has hostile intentions, it is not at all certain that the adversary will take the risk of launching an attack. It depends on the risk aversion of the adversary. If the adversary requires a high probability of attack success before he will launch an attack, the risk aversion is high. If, on the other hand, the adversary only requires a low probability, the risk aversion is low. The risk aversion of the adversary, like the intention of the adversary, is subjective. The party has no certain knowledge about the risk aversion of the adversary. Nevertheless, the party will make his own evaluation of the adversary's risk aversion. This is another important issue and will influence the military capability, that the party considers necessary.

27. The **combat outcome**, in case of an attack, is considered. The combat outcome depends on many factors. The relative strength of the adversary's offensive military capability and the party's defensive military capability are among these. The outcome of the combat cannot be predicted with certainty. Predictions are usually obtained by applying military judgement in combination with suitable mathematical combat models. However, experience has shown that military judgement and various combat models may differ in predictions of combat outcomes. The party has established a stable defence if the defensive military capability of the party is sufficient to repel the attack from the adversary.

28. The **security need** of a party specifies the degree of stability that a party requires in the relation to the adversary. If the security need of the party is satisfied, the party is confident with regard to the existence of a *unilateral stable defence.*

29. It is obvious that it is not possible for the party on a purely objective basis to determine the military capability necessary to assure a stable defence because of the subjective factors going into the determination of stability.

30. These considerations lead to the following definition of a unilateral stable defence in a bipolar situation:

A party has established a *unilateral stable defence* against an adversary if the security need of the party is fulfilled. This is the case if the party is confident that: the adversary has no intention of launching an attack, or the adversary cannot accept the risk of attacking, or an attack can be repelled.

2.2.2 Conceptual model for unilateral stable defence in a many-on-one situation

31. A situation with a region consisting of more than two parties is investigated. The security and defence issues of *one party* with respect to the other parties, *the adversaries*, are examined. The adversaries act independently of each other. If there were any special agreements or treaties between two adversaries to participate in hostile actions against the party the adversaries would be considered as one adversary.

32. The party has to consider the following aspects:

- intentions of each adversary
- risk aversion of each adversary, if attack is considered
- combat outcomes in case of one or multiple attacks
- security need of the party

33. The assessments of the first two aspects are similar to the assessments in the bipolar case. However, an attack from one adversary may change the situation for the other adversaries. The defensive strength of the party may be reduced by the first attack, and if hostile intentions exist for other adversaries, this reduction may imply that the risk of launching an attack by other adversaries may become acceptable. Although the adversaries are acting independently of each other, an attack from one adversary will change the expectations with respect to the outcome of an attack from other adversaries. The fourth aspect, the security need of a party, specifies the level of stability that a party requires in the relation to all other adversaries.

34. The definition of unilateral stability in the many-on-one situation becomes:

A party has established a *unilateral stable defence* against the adversaries within a region if the security need of the party is fulfilled. This is the case, if the party is confident that: the adversaries have no intention of launching an attack, or the adversaries cannot accept the risk of attacking, or any attack can be repelled.

2.3 MULTIPOLAR STABILITY

35. If all parties within a region consider to have established a unilateral stable defence, the region is named a multipolar stable defence system:

A region is a *multipolar stable defence system* if all parties within the region have established a unilateral stable defence.

36. The subjective factors relevant for the definition of unilateral stable defence make it impossible to develop an objective measure for multipolar stability within a region.

37. Of course each party in the region can make its own subjective evaluations of the situation and decide if its security needs are fulfilled. A unilateral stability evaluation can be carried out by each party in the region.

38. The stability aspects of different parties are interrelated through their military capabilities. The defensive military capability of a party and the offensive military capabilities of the adversaries are prerequisites for evaluating the prospect of repelling attacks. A modification of the defensive and the offensive military capability of a party will change the ability of repelling attacks from other parties, but will also change other parties' abilities of repelling attacks from the party. For each party the influence of the military capabilities on stability can be further investigated. An assessment of a lack of own defensive military capability or an excess of hostile offensive military capability can be performed.

39. Although it is impossible to developed an objective measure for multipolar stability within a region, it is of course possible for any party to make its own regional stability evaluation. Any party from inside or outside the region may perform the subjective evaluation with respect to intention, risk aversion, repel of attack and security needs for any other party within the region. In this way the party may evaluate its belief of the existence of a multipolar stable defence system.

40. Especially, an international party that wants to establish a military multipolar defence system may perform its own evaluation. If a multipolar stable defence system is considered not to exist, the international party may assess the lack of defensive military capability and determine the requirements to an international force that may guarantee stability.

CHAPTER 3

MATHEMATICAL REPRESENTATION OF MILITARY STABILITY

3.1 GENERAL

41. A mathematical model provides the possibility to study the relations between relevant factors in a clear and specific way and to set up a quantitative measure for the degree of stability. From the conceptual model of unilateral stability a simple model for the bipolar situation is developed. This model is generalised to a first order many-on-one situation by introducing a simplifying assumption with regard to independence between the actions of the parties. In Annex V, a model is derived without this simplifying assumption. Based on the unilateral probability of stability two simple measures for regional multipolar stability are proposed.

3.2 UNILATERAL STABILITY

3.2.1 Mathematical model for unilateral stable defence in a bipolar situation.

42. A mathematical model of unilateral stable defence for a party against an adversary is developed. The mathematical model includes the following parameters:

P_I The probability that the adversary may have hostile intentions with respect to the party within the period considered.

43. Note, that P_I is the party's subjective probability (degree of belief) regarding the adversary's intention.

P^* The adversary's risk aversion concerning an attack against the party. The minimum probability that the adversary requires for success in order to attack.

44. Conditioned on the adversary having intentions to attack, the adversary will not carry out an attack, if the probability of attacker combat success is less than the risk aversion.

45. Note, that P^* is the party's estimate of the adversary's risk aversion.

W Probability that the defender is able to repel the attack in case of aggression against the party.

46. This probability is based on military judgement and mathematical combat models.

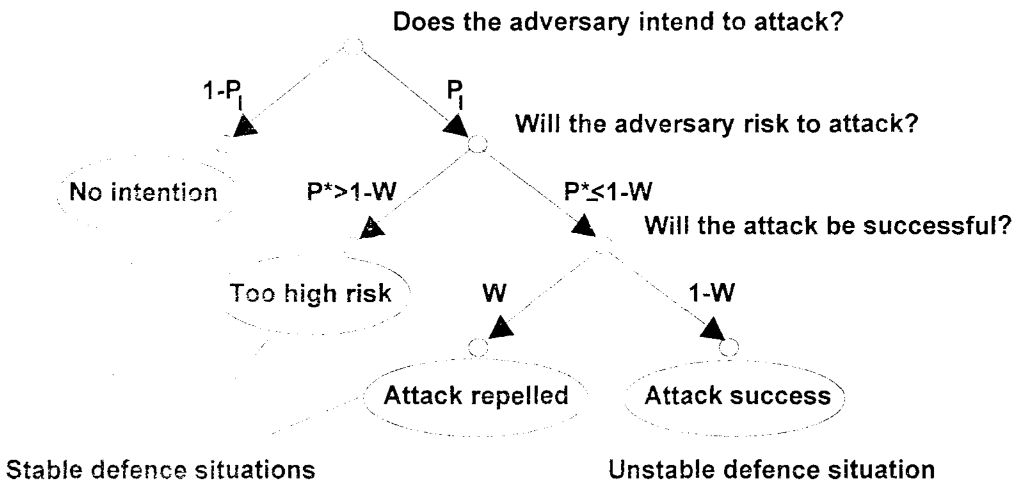

FIGURE 3.1 Stability aspect for a party in a bipolar situation.

P_S Probability of unilateral stability for the party.

47. P_S is determined as 1 minus the probability for the complementary event of a transition to the unstable state:

$$P_S = \begin{cases} 1, & P^* > 1 - W \\ 1 - P_I(1 - W), & P^* \leq 1 - W \end{cases} \tag{3.1}$$

48. A more compact formula for P_S is achieved by introducing a step function G that equals 1 if $1\text{-}W \geq P^*$, and equals 0 otherwise.

$$G(1 - W; P^*) = \begin{cases} 1; & 1 - W \geq P^* \\ 0; & 1 - W < P^* \end{cases} \tag{3.2}$$

49. The probability of a unilateral stable defence then becomes

$$P_S = 1 - P_I G(1 - W; P^*)(1 - W) \tag{3.3}$$

50. P_S takes the value 1 when the party considers the situation to be absolutely stable. If the party requires a probability of unilateral stability equal to one, significant military forces may be required.

51. Obviously the existence of unilateral stability is a stochastic phenomenon characterised by a probability of stability. In practice a party specifies in accordance with his security needs a probability that he considers sufficient to have established unilateral stability. So the party determines a minimum acceptable level for the probability of stability, P_{min}.

P_{min} Security need (the minimum required probability of stability by the party.)

52. **Condition for unilateral military stability for a party in a bipolar situation:**

$$P_s \geq P_{\min}. \tag{3.4}$$

53. The mathematical expression for the probability of stability is illustrated by a 3-dimensional plot of P_S as a function of the probability of an attack intention, P_I, the probability of defender success in combat, W, and for a given specific value of the attacker's risk aversion, P^*.

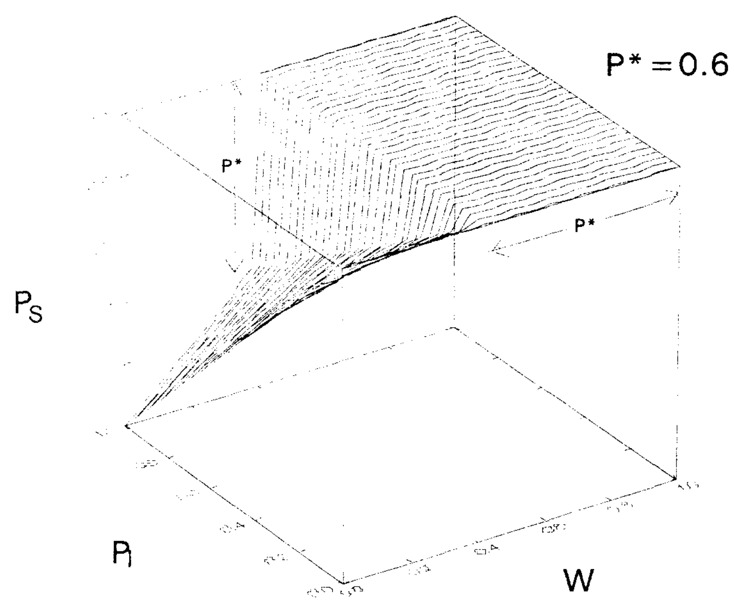

FIGURE 3.2 Three-dimensional plot of P_S as a function of P_I and W given $P^* = 0.6$.

54. In figure 3.3, P_S is represented by a contour diagram as a function of P_I and W for given a value of P^*.

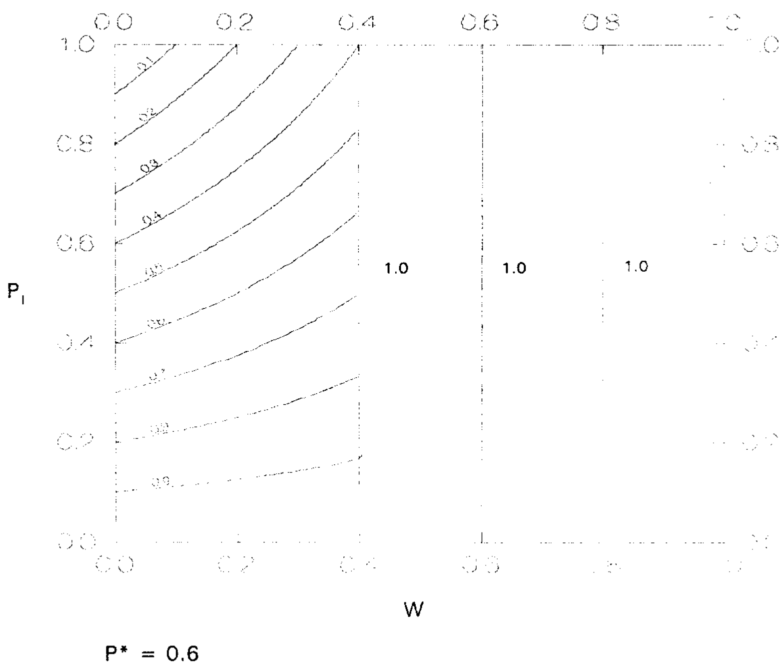

FIGURE 3.3 Contour diagram for P_S as a function of P_I and W, given P*=0.6.

55. If the security need, P_{min}, is 0.8 then the part of the contour diagram "South and East" to the contour curve, corresponding to $P_S = 0.8$, represents combinations of P_I and W, which the defending party considers representing stability.

56. Normally, the defender will have no immediate influence on the risk aversion, P^*, and the probability, P_I, of an attack intention. But the defender may increase the probability, W, of combat success in case of attack by improving the defence capability.

57. The formula for the unilateral stability probability clearly shows that an increase of the defence capability (increase of W) cannot result in a reduction of the unilateral stability.

3.2.2 Mathematical model for unilateral stable defence in many-on-one situation.

58. The condition for a unilateral stable defence in a bipolar situation with a single adversary has been explored above. This situation is generalised to a many-on-one situation. The unilateral stability is considered for a party in a region with many adversaries. It is assumed that no co-operation exists between adversaries. If this was the case, co-operating adversaries would be considered as a single adversary.

59. For simplicity an approximate development is carried out in this chapter. Here it is assumed that actions by an adversary do not changes the situation for other adversaries. A more rigorous treatment in which an attack from one adversary changes the situation for the other adversary is carried out in Annex V.

60. It is assumed that intentions, risk considerations and expectation of a successful outcome of an aggression will remain unaltered no matter what actions other adversaries may perform.

61. A region with i=1,...,N parties are considered. The probability of unilateral stability for party i is developed. The remaining adversaries may consider hostile actions. First the situation for party i and adversary j is investigated. The probability of stability for this situation corresponds to the probability of unilateral stability for the bipolar situation:

$$P_{Sj}^{i} = 1 - P_{Ij}^{i} G\left(1 - W_j^i ; P_j^{*i}\right) \tag{3.5}$$

62. The superscript i relates to party i. The subscript j relates to adversary j.

P^i_{Ij} The probability that the adversary j may have hostile intentions with respect to party i within the period considered.

$P_j{*^i}$ The risk aversion of adversary j concerning an attack against the party i. The minimum probability that the adversary requires for success in order to attack.

W_j^i Probability that party i is able to repel the attack in case of aggression from adversary j.

$P_{Sj}{}^i$ Probability of stability for the party i against adversary j

$P_S{}^i$ Probability of unilateral stability for the party i

$P^i{}_{min}$ Security need (the minimum required probability of stability by the party i.)

63. All the adversaries act independently of each other. Accordingly, the probability of unilateral stability for party i becomes

$$P_S^i = \prod_{j \neq i}^{N} P_{Sj}^i \tag{3.6}$$

64. The probability of unilateral stability for party i is compared with the security need for party i. The condition for unilateral military stability i a many-on-one situation becomes:

$$P_S^i \geq P_{min}^i . \tag{3.7}$$

65. The formula for the probability of unilateral stability for party i is an approximation that corresponds to a *first order* evaluation. It describes a situation with independently acting adversaries and thus no adversaries taking advantage of the situation. The formula is adequate if it can be assumed that all adversaries may cause instability, but the effect of the follow-on actions by other adversaries may be of minor importance.

66. Introducing follow-on actions by other adversaries cannot increase the probability of unilateral stability, therefor the formula corresponds to an upper bound for the probability of unilateral stability. If the upper bound is less than the security need for the party the situation is unstable. The exact probability of unilateral stability is derived in Annex V.

3.3 DIFFERENT VIEWS ON UNILATERAL STABILITY

67. A party has established a *unilateral stable defence* against an adversary if the security need of the party is fulfilled. This is the case, if the party is confident that: the adversary has no intention of launching an attack, or the adversary cannot accept the risk of attacking, or an attack can be repelled.

68. This definition considers the intention as well as risk aversion and the military capability of the defence to repel an attack from an adversary. The definition is said to provide a *confidence view* on a unilateral stable defence for a party. The view is to a high extent subjective. There is no sure way to assess intentions of other adversaries or their risk attitude. It might be relevant to consider other views on unilateral stability with less emphasis laid on the assessment of the intentions of adversaries. The two different views presented below are special cases of this confidence view.

69. The *sufficiency view* is only based on an assessment of the risk aversion of the adversary. The adversary is presumed to consider the risk of an aggression as being unacceptable if his victory probability does not exceed a certain threshold value. The value describes the minimum probability that the adversary requires for success in order to attack. A risk averse adversary would demand a high minimum probability, a risk prone adversary would accept a lower probability. Even though the threshold value is never stated explicitly an acceptable level is assumed to be very high. The sufficiency view infers that the security need of a party is fulfilled if an adversary is considered not willing to accept the risk of launching an attack.

70. The *security view* is based on an assessment of the defence capability of the party. The party considers the situation as being stable if the probability of repelling an attack

exceeds another threshold value. The value describes the minimum acceptable probability that the party requires for a successful defence. A risk averse party requires a high probability, a risk prone party would accept lower probabilities. The security view does not include subjective assessment of the intention and risk aversion of adversaries, but only considers the military capabilities and the probability of a successful defence. The security view assumes that the security need of a party is fulfilled if the probability of a successful defence is sufficiently high.

71. The three views on stability place different constraint of the military forces. The confidence view is the less demanding and the security view is the most demanding with respect to the defensive military capability.

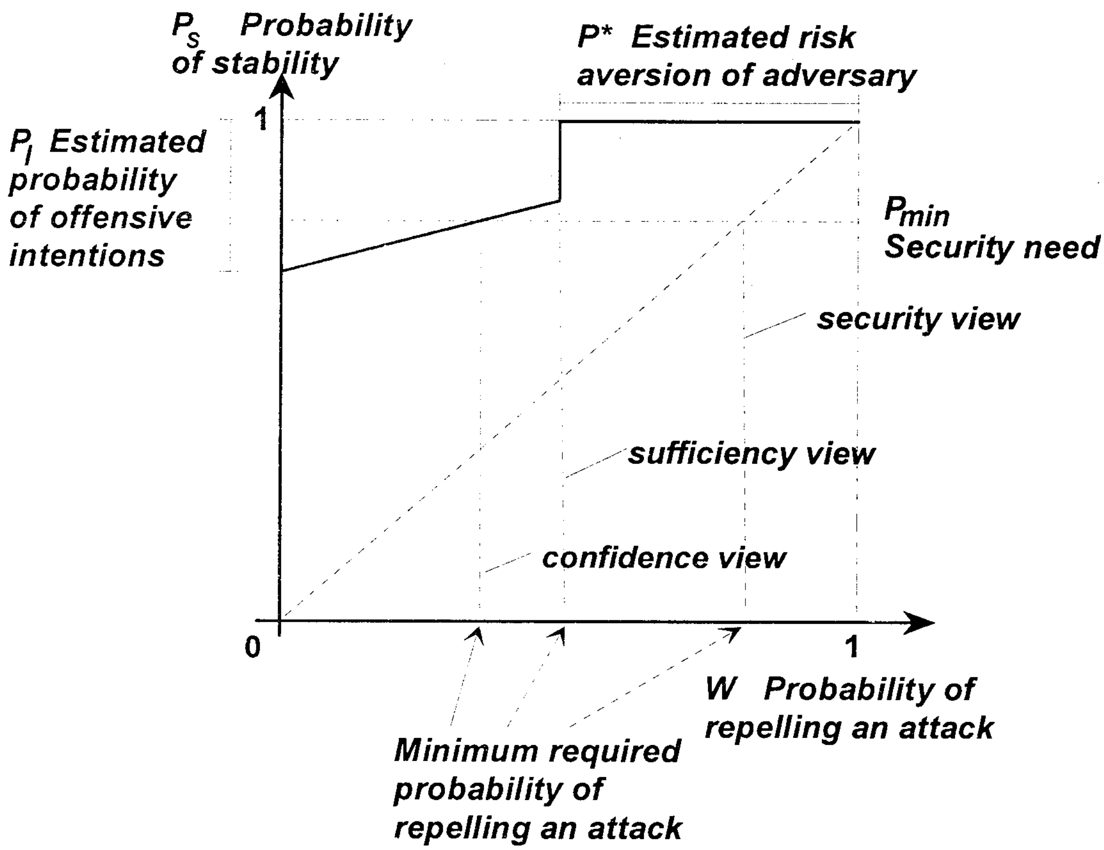

FIGURE 3.4 The minimum required probability of repelling an attack is given for the three stability views. The confidence view combines the security level with the adversary risk aversion and offensive intentions. The sufficiency view addresses the risk aversion. The security view addresses the security need.

3.4 MULTIPOLAR STABILITY

72. A region is a *multipolar stable defence system* if all parties within the region have established a unilateral stable defence. The subjective factors relevant for the definition of unilateral stable defence make it impossible to develop an objective measure for multipolar stability within a region. In order to understand the interrelations between the unilateral stability aspects of different parties in the region, it is worthwhile to the extent possible, to integrate the unilateral stability considerations for the parties and provide measures for multipolar stability.

73. A measure for multipolar stability makes it possible to show the consequence for multipolar stability by changing the sizes and structures of military forces. Many different measures can be developed; but due to the interrelations of the unilateral stability, only two very rough measures of multipolar stability are proposed.

- The first measure of multipolar stability is established by considering the party within the region that has the worst stability condition and applying the probability of unilateral stability for that party as a measure of multipolar military stability.

- The second measure of multipolar stability is derived by multiplying the probabilities of unilateral stability for the individual parties.

74. The first measure implies that multipolar stability can only be enhanced by improving the stability for the party within the region that has the smallest probability of unilateral stability. Improving stability for other parties will have no influence on this stability measure; but of course on the unilateral stability for the parties improving their capabilities. The second measure, the product of probabilities of unilateral stability, is sensitive to any changes of the stability aspects but, like the first measure, it does not provide any interpretable probabilistic description of multipolar stability. However both are relevant for comparison of different situations.

75. As a simple example consider a region with two parties. The probabilities of unilateral stability are equal to P_S^1 and P_S^2, respectively. For a friendly party within the region a measure of regional stability would be equal to their own probability of unilateral stability. They know their own intentions and are only concerned about actions by the other party. So their estimate of multipolar stability would correspond to their own probability of unilateral stability. From outside the region, the two measures: $\min(P_S^1, P_S^2)$ and $P_S^1 * P_S^2$ may both reveal important stability aspect when comparing different situations, but do not express any probability of multipolar stability.

76. Both measures of multipolar stability is based on the probabilities of unilateral stability. The evaluations with respect to stability that each party performs can in principle be carried out by any party, any international organisation etc. In this way any party may assess a unilateral probability of stability for all the parties in the region and combine these to a measure of multipolar stability.

77. The multipolar stability measures are based on the unilateral stability probabilities of all the parties in the region. A region with i=1,...,N parties are considered. The probability of unilateral stability for party i equals $P_S{}^i$.

M_S The minimum probability of unilateral stability.

$$M_S = \min\left(P_S^1, P_S^2, \dots, P_S^N\right) \tag{3.18}$$

O_S The product of the probabilities of unilateral stability

$$O_S = \prod_{i=1}^{N} P_S^i \tag{3.19}$$

78. To illustrate the measures for multipolar stability, consider a region with four parties having different military forces, different intentions with respect to hostile activities, and different risk attitudes. Parties 1 and 2 are relative small and friendly parties, party 3 has a greater military force and is more hostile, and, finally, party 4 is the greatest and most hostile party. The explicit values are given i table 3.1.

TABLE 3.1 A fictious example. Multipolar system with 4 parties. The intention and risks for a party, P, are specified for possible adversaries, A.

Party	Forc	Intentions			P_I		Risks			P*	
	siz	A\P	1	2	3	4	A\P	1	2	3	4
1	500	1		0.01	0.01	0.01	1		0.95	0.95	0.95
2	500	2	0.01		0.15	0.20	2	0.90		0.90	0.90
3	1000	3	0.15	0.25		0.30	3	0.85	0.85		0.85
4	2000	4	0.20	0.40	0.60		4	0.80	0.80	0.80	

79. The probability of repelling an attack is given as a function of the attacker to defender force ratio. A simple description is applied. An attacker to defender force ratio equal to 3 results in a probability of repelling the attack equal to 10%. A force ratio equal to 1.5 gives a probability of repelling the attack equal to 90%. This simplistic formulation of repelling of an attack does not explicitly take into account the composition of forces, the preparedness, the terrain, etc.

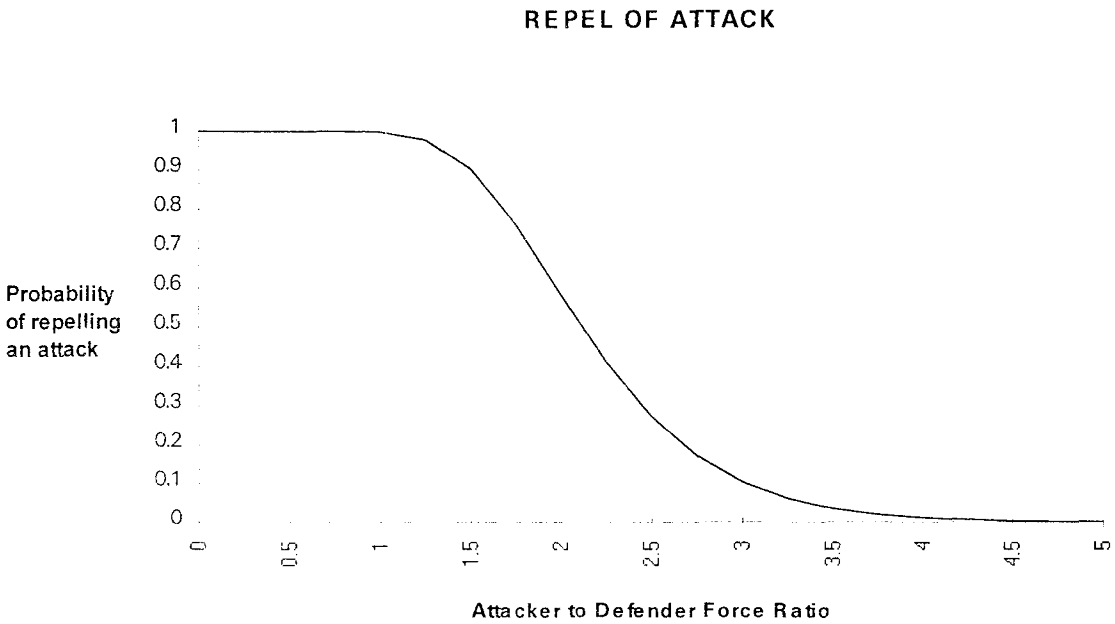

FIGURE 3.5 Probability of repelling an attack as a function of attacker to defender force ratio

80. A first order estimate for the probability of unilateral stability is calculated. The probabilities become 0.802, 0.605, 1 and 1 for party 1, 2, 3 and 4 respectively. The calculations reveal that party 1 and 2 is threatened only by party 4. The probability of multipolar stability given as the minimum probability of unilateral stability equals M_S=0.605 and the product of probabilities of unilateral stability equals O_S=0.485.

81. The multipolar stability can be enhanced by at least four different means, that will be described below and exemplified based on the example:

- Stabilisation of region by stabilisation of the individual parties.
- Stabilisation of region by co-ordinated adjustment of military forces.
- Stabilisation of region by defence treaties.
- Stabilisation of region by international force.

3.4.1 Stabilisation of Region by Stabilisation of the Individual Parties

82. The multipolar stability can be enhanced by providing the weaker parties with more defensive military capability. For each individual party the defensive military capability of the military system should be increased such that security need of the party is satisfied without disturbing the security needs of other parties. In order not to disturb the security needs of other parties the existence of weapon systems with a substantial defensive military capability and no essential offensive military capability may be required. Such systems are denoted non-offensive defence systems (NOD). Dependent on the situation, it could turn out to be an expensive way to a multipolar stable defence system. The advantage of the approach is that it not requires any co-ordination between the parties of the region.

83. The effect of adding non-offensive defence forces to the weaker parties 1 and 2 is illustrated in figure 3.6.

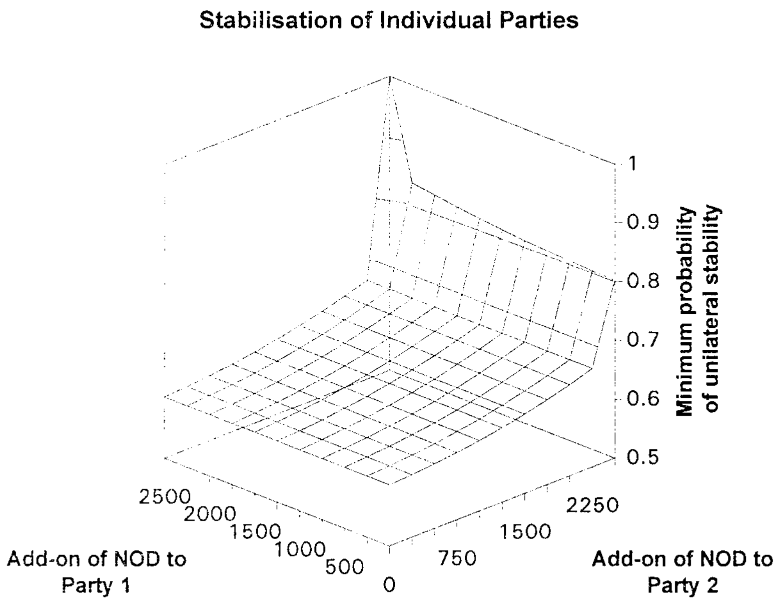

FIGURE 3.6 The minimum probability of unilateral stability increases by adding non-offensive defence forces (NOD) to party 1 and 2.

3.4.2 Stabilisation of Region by Co-Ordinated Adjustment of Military Forces.

84. The multipolar stability can be enhanced by a co-ordinated adjustment of the military forces of the region. A reduction of the forces of the stronger parties and a

reinforcement of the weaker parties by increasing the defensive military capability are means for establishing stability. The co-ordination should be carried out such a way that the security needs of all parties are fulfilled. The increment of the defensive military capability may require weapon systems with essentially no offensive military capability.

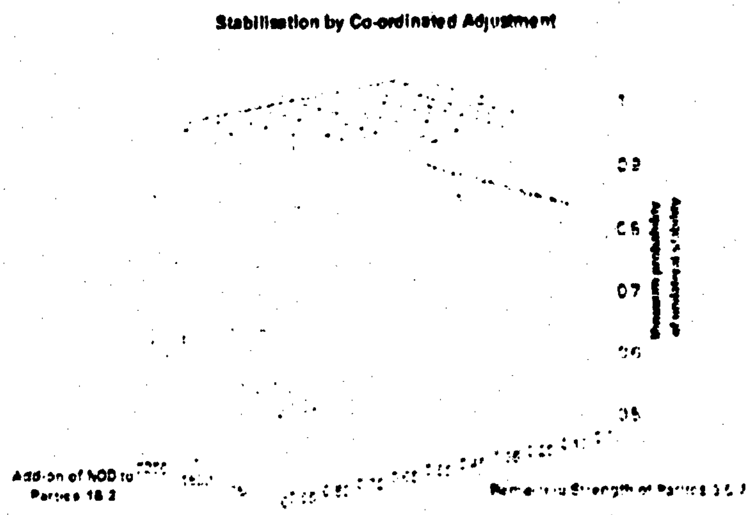

FIGURE 3.7 The minimum probability of unilateral stability displayed for different adjustments of the forces of the region. The weaker parties (1 & 2) may increase their defensive military capability by adding non-offensive defence forces, the stronger parties (3 & 4) may reduce their forces

85. Figure 3.7 shows the influence of strengthening the defence of the weaker parties 1 and 2, and weakening the strong parties 3 and 4 by reducing their forces. For simplicity the same add-on of non-offensive defence forces for parties 1 and 2 and the same reduction factor for parties 3 and 4 have been used. If the reduction of the forces of parties 3 and 4 is extreme, the defensive capabilities of these parties become insufficient to ensure their own stability.

3.4.3 Stabilisation of Region by Defence Treaties.

86. The multipolar stability can be enhanced by establishing defence treaties between the parties within the region such that the security needs of all parties are fulfilled. If this approach is possible it could be a less expensive way to a multipolar stable defence system than the others means mentioned above.

87. The concept is illustrated by considering a commitment of forces by each party to the defence of other parties. In case of an attack on one party by another party within the region, the other parties have to commit a agreed fraction of their forces to the defence of the attacked party.

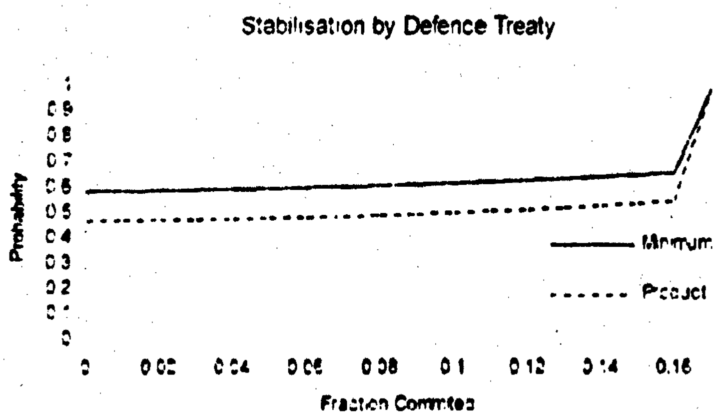

FIGURE 3.8 The influence of a defence treaty for the internal stability of the region is displayed. If a party is attacked by another party within the region, the remaining parties commit a fraction of their forces to the defence of the attacked party. The minimum probability of unilateral stability, M_S, and product of the probabilities of unilateral stability, O_S, are shown.

88. Each party agrees to commit a certain fraction in accordance with the defence agreement. Any party, which is attacked by another party within the region, will have their defence reinforced by the committed forces. In the example, a common agreed commitment factor for all parties equal to 0.17 is sufficient for establishing a multipolar defence system.

3.4.4 Stabilisation of Region by International Force

89. An international force may provide the additional defensive military capability for the regional multipolar stability. If a party within the region is not able to set up the necessary defence for unilateral stability the international force may guarantee to provide the additional defensive military capability. If the international force gives such a guarantee to all parties of the region, a multipolar stable defence system is established. The international force may be created by UN, NATO, a third party, etc. In this way stability may be established without co-ordination between the parties.

90. However, dependent on the military capabilities of the parties within the region the establishment of stability may require a large international force. For a specific international force stability may only be provided, if some of the parties reduce their forces.

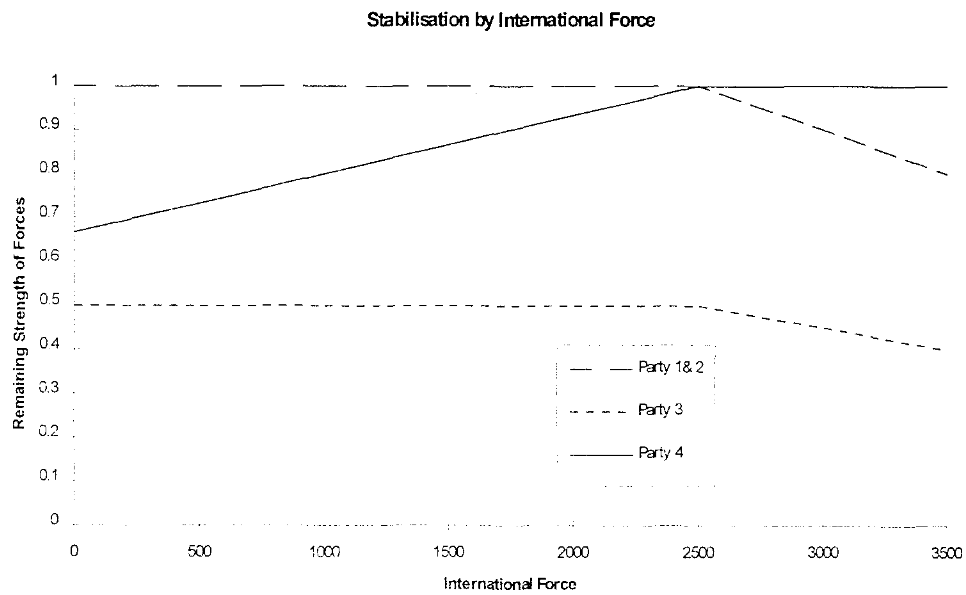

FIGURE 3.9 An international force creates stability by providing the necessary defensive military capability. For different sizes of an international force the necessary reduction of forces to achieve a multipolar stable defence system are shown.

91. Figure 3.9 shows the necessary reduction of the forces of the parties within the region as a function of the size of the international force. If no arms reduction is carried out an international force of size 2500 is demanded in order to achieve multipolar stability. If a smaller international force is provided, it is necessary that the major forces in particular reduce their size. The figure shows the maximum relative size of the party 4 (the major force) and the possible reductions of other forces for a given remaining strength of party 4.

CHAPTER 4

MILITARY FACTORS INFLUENCING MILITARY STABILITY

4.1 GENERAL

92. What properties of a military posture might be most conducive to stability as defined above? To answer this question it will be useful to begin by describing a set of explicit hypotheses. This serves several purposes.

93. First, an explicit catalogue of hypotheses illustrates the breadth and complexity of the military issues associated with stability. Since no single study can hope to address more than a subset of these issues, to catalogue them as broadly as possible serves to set the analyses that were conducted into proper context.

94. Second, such a list provides a research agenda to encourage further investigation. A complete understanding of such a complex problem will require an accumulation of insights by multiple researchers over a considerable period of time. The cumulation of knowledge (on this or any other subject) is facilitated to the degree that different researchers coordinate their work around a set of interrelated questions. An explicit list of hypotheses provides a vehicle for such coordination, and should thus assist in the longer term growth of knowledge on military stability.

95. Third, such a list should facilitate the development of policy recommendations even before the growth of knowledge yields complete understanding. The debate on stability is often driven by the assumptions of the respective parties. Often these assumptions are implicit rather than explicit. As a result, the debate is too often clouded by failure of the parties to recognize and examine the underlying contentions of fact or interpretation that motivate their respective positions. To make these underlying contentions explicit, and to list them as comprehensively as possible, may thus encourage a more productive public debate on stability generally (and even on aspects not analyzed in detail here).

96. Finally, and perhaps most important for our purposes, an explicit list of hypotheses may facilitate simulation analysis by identifying a discrete set of questions for the simulations to address. Modern simulation models incorporate a host of variables and are capable of examining a wide range of forces, tactics, and environmental conditions. To

organize a meaningful set of analyses using such tools thus requires limiting the universe of possible scenarios to a tractably small set whose results enable us to reach important conclusions about stability. An explicit list of hypotheses derived from the larger public debate provides a means of identifying such a set of scenarios. It provides a set of factual propositions whose importance is derived from their role in the public deliberation, and which can be substantially refuted, corroborated, limited or modified by the results of a relatively small number of carefully specified simulation runs. As such, it offers an organizing tool of considerable value for integrating the results of several different simulation models and a variety of diverse scenario conditions.

4.2 HYPOTHESES

97. Hypotheses on military stability may be grouped into six broad categories: hypotheses relating to strategic factors; general military factors; force components; factors specific to certain parties; the nature of the international system; and the nature of domestic political, economic, or social structures.

98. It should be strongly emphasized that the hypotheses listed here are propositions to be examined by simulation (or other) analysis -- they are *not* analytical conclusions in themselves, and their inclusion per se represents no conclusion as to their ultimate validity. They have been selected solely on the basis of their role in the larger debate on stability, and their utility in illustrating the range of issues encompassed by that debate, but *not* because they either represent or contradict the views of any study participants (indeed, it is highly unlikely that any single individual would subscribe to the entirety of such a diverse set of propositions). Nor are the hypotheses given here intended to provide an internally consistent list; as they were chosen for consistency with the larger debate (which contains many contradictory arguments), mutually contradictory but widely held ideas are thus juxtaposed where appropriate. Finally, it should be noted that many interaction effects could be identified between individual hypotheses. To account for all such possibilities, however, would be beyond the scope of this analysis; the focus here is thus on identifying the most important first order propositions regarding stability, rather than enumerating all possible combinations of possible interactions among them.

4.2.1 Hypotheses Relating to Strategic Factors

99. Strategic factors relevant to military stability include strategic conceptions and resulting military doctrines; scientific, industrial, and economic capabilities; terrain and militarily relevant infrastructure; mobilization capabilities and postures; and force ratios.

4.2.1.1 Strategic Conceptions and Resulting Military Doctrine

100. It could be hypothesized that:

a. *Doctrines emphasizing defensive depth are stabilizing*, by, in principle, permitting defenders time to counterconcentrate, by reducing the coherence of offensive units as they advance into depth, and/or by increasing the exposure of an invader's flanks to counterattack.

b. *Doctrines emphasizing large mobile reserves are stabilizing*, by, in principle, reducing the fraction of the defender's forces that can be pinned in place in forward positions away from the invader's point of attack, and thereby increasing the size of the force the defender can ultimately counterconcentrate against the invader's point of attack.

c. *Doctrines emphasizing counterattack are stabilizing*, by, in principle, forcing invaders to divert forces from use in offensive spearheads to use in flank defenses, or by causing a more rapid loss of offensive coherence over the course of an extended advance into defensive depth.

d. *Doctrines emphasizing rapid closure with the enemy are destabilizing*, by, in principle, reducing the reaction time available to defenders prior to offensive breakthrough.

e. *Doctrines emphasizing narrow offensive frontages are destabilizing*, by, in principle, enabling invaders to concentrate their forces to achieve higher local force-to-force ratios for a constant theater balance.

f. *Doctrines emphasizing initiative and flexibility are destabilizing*, by, in principle, providing command traits more necessary for offensive improvisation than for defensive reaction.

4.2.1.2 Scientific, Industrial and Economic Capabilities

101. It could be hypothesized that:

a. *Design/prototyping (vice production) capability is stabilizing*, by, in principle, providing states with latent defensive capabilities for response to unanticipated threats without posing short warning threats-in-being to neighboring states in the meantime.

b. *Surge production capability is destabilizing*, by, in principle, providing states with rapid buildup capabilities, making threats harder for states to anticipate and plan against.

c. *Multinational military production is stabilizing*, by, in principle, requiring consensus among several states to the production of any given weapon type, making it less likely that one party could secure agreement to produce systems that threaten the others.

d. *Production base survivability is stabilizing*, by, in principle, reducing incentives for preemptive attack.

e. *Defense conversion capability is stabilizing*, by, in principle, reducing the needs of states to retain military production capacity (which neighbors may find threatening even if the state means no hostile intent) for reasons of domestic employment.

f. *Strategic stockpiling of key materiel is stabilizing*, by, in principle, by reducing incentives for preemptive attack of strategic lines of communication and resupply.

4.2.1.3 Terrain and Militarily Relevant Infrastructure

102. It could be hypothesized that:

a. *Close terrain is stabilizing*, by, in principle, increasing the availability of defensive cover, facilitating the construction of defensive obstacles, and slowing the tempo of offensive operations.

b. *Open terrain is destabilizing*, by, in principle, reducing the availability of defensive cover, complicating the construction of defensive obstacles, and increasing the tempo of offensive operations.

4.2.1.4 Mobilization Capabilities and Posture

103. It could be hypothesized that:

a. *Rapid mobilization capability is destabilizing*, by, in principle, reducing warning time and facilitating surprise attack.

b. *Peacetime garrisoning near disputed borders is destabilizing*, by, in principle, reducing warning time and facilitating surprise attack.

c. *Rapid demobilization is destabilizing*, by, in principle, creating weaknesses through organizational turmoil that create opportunities for opposing attack.

4.2.1.5 Force Ratios

104. It could be hypothesized that:

a. *High force-to-force ratios are destabilizing*, by, in principle, enabling invaders to overwhelm smaller defending forces.

b. *Low force-to-space ratios are destabilizing*, by, in principle, stretching defensive forces too thinly to resist in sufficient numbers at any single point, and/or creating opportunities for more offense-favorable non-linear, maneuver warfare methods.

4.2.2 Hypotheses Relating to General Military Factors

105. General military factors relevant to military stability include training and morale; force readiness; logistic posture; command, control and communications capabilities; and intelligence collection, target acquisition and surveillance capabilities.

4.2.2.1 Training and Morale

106. It could be hypothesized that:

a. *Large scale offensive exercises are destabilizing*, by, in principle, training attackers in large unit operations necessary for invasion but less necessary for defense, and/or by making it easier for invaders to mask attack preparations as peacetime exercises.

b. *Large scale exercises near disputed borders are destabilizing*, by, in principle, making it easier for invaders to mask surprise attack preparations as peacetime exercises.

c. *Frequent training in offensive tactical routines is destabilizing*, by, in principle, preparing forces for offensive warfare.

d. *Concealment of training is destabilizing*, by, in principle, denying defenders a source of early warning of offensive preparations by neighboring states.

e. *Highly trained/skilled/motivated/influenced forces are destabilizing*, by, in principle, providing attackers with the high troop quality most necessary for the more challenging tasks of offensive warfare.

f. *Professional forces are destabilizing*, by, in principle, providing attackers with the high troop quality most necessary for the more challenging tasks of offensive warfare, and/or by isolating the armed forces from the values and norms of civil society.

g. *Conscript forces are stabilizing*, by, in principle, reducing the experience level of the troops and thus reducing (*ceteris paribus*) the high troop quality most necessary for the more challenging tasks of offensive warfare, and/or by reducing the isolation of the armed forces from the values and norms of civil society.

4.2.2.2 Force Readiness

107. It could be hypothesized that:

a. *High peacetime readiness is destabilizing*, by, in principle, increasing capabilities for surprise or short warning attacks.

b. *Inability to sustain high readiness/alert levels over extended time periods is destabilizing*, by, in principle, confronting states with "use-or-lose" dilemmas when forces are mobilized or alerted.

4.2.2.3 Logistic Posture

108. It could be hypothesized that:

a. *Mobile logistical capabilities are destabilizing*, by, in principle, permitting invaders to sustain military operations while advancing onto enemy soil.

b. *Static/low mobility logistical capabilities are stabilizing*, by, in principle, enabling defenders to sustain military operations on their own soil, while reducing the invader's ability to sustain an advance onto enemy soil.

4.2.2.4 Command, Control and Communications Capabilities

109. It could be hypothesized that:

a. *Communications capabilities are stabilizing*, by, in principle, strengthening the defender's ability to react in response to offensive initiatives (while offering lesser benefits to attackers who know their own plans in advance).

b. *Navigation capabilities are destabilizing*, by, in principle, facilitating an attacker's advance over unfamiliar terrain.

4.2.2.5 Intelligence Collection, Target Acquisition and Surveillance Capabilities

110. It could be hypothesized that:

a. *Surveillance capabilities are stabilizing*, by, in principle, increasing a defender's ability to obtain warning of attack, and to locate the invader's point of main effort.

b. *Deep target acquisition capabilities are destabilizing*, by, in principle, enabling an attacker to destroy targets deep on the defender's soil without first breaking through the defender's forward forces.

c. *Short range target acquisition capabilities are stabilizing*, by, in principle, increasing local defenders' ability to employ indirect fires from covered positions.

d. *Knowledge of opposing order of battle/doctrine/equipment is stabilizing*, by, in principle, providing warning of offensive preparations and the development of offensive capabilities and permitting timely counteractions.

e. *Mobile jamming/deception capabilities are destabilizing*, by, in principle, enabling attackers to extend the benefits of jamming and electronic deception to moving formations advancing onto enemy soil.

f. *Static/low mobility jamming/deception capabilities are stabilizing*, by, in principle, reducing attackers' ability to extend the benefits of jamming and electronic deception to moving formations advancing onto enemy soil.

g. *Cover, concealment and camouflage capabilities are stabilizing*, by, in principle, increasing the combat effectiveness of stationary defenders (who can more fully exploit the potential of cover, concealment and camouflage than can moving attackers).

4.2.3 Hypotheses Relating to Force Components

111. Force components relevant to military stability include armor; infantry; artillery; counter-mobility capabilities; obstacle breaching and crossing capabilities; air defense; air mobility and mechanization of land forces; battlefield ground attack air capabilities; offensive counter-air capabilities; deep interdiction capabilities; and defensive counter-air capabilities.

4.2.3.1 Armor

112. It could be hypothesized that:

a. *Tanks (defined as per CFE Treaty language) are destabilizing*, by, in principle, providing mobile, protected firepower essential for advancing under fire.

4.2.3.2 Infantry

113. It could be hypothesized that:

a. *Infantry*[1] *is stabilizing because it cannot successfully assault a defended position*, as, in principle, it lacks the armor protection, or mobile firepower necessary to advance under fire.

b. *Infantry is stabilizing because it cannot successfully assault a position defended by armored vehicles*, as, in principle, it lacks the mobile firepower required to destroy hard targets.

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[1] "Infantry" refers to Dismounted infantry, with or without armored transport.

c. *Infantry is stabilizing because it cannot successfully assault a defended position without prohibitively heavy/prolonged offensive artillery/air support*, as, in principle, it requires extensive fire support to weaken defensive positions sufficiently to permit thin-skinned vehicles and personnel to advance under fire.

d. *Infantry is stabilizing because it cannot successfully assault a defended position in open terrain*, as, in principle, it requires extensive use of natural cover to advance under fire.

e. *Infantry is stabilizing because it requires a prohibitively large local/theater force ratio to succeed in an attack*, as, in principle, thin-skinned infantry units will suffer higher losses than armor in an advance under fire, and thus would require a larger force to accomplish the same mission.

4.2.3.3 Artillery

114. It could be hypothesized that:

a. *Artillery is stabilizing*, by, in principle, enabling defenders to counterconcentrate by fire rather by the (slower) movement of ground forces.

b. *Self-propelled artillery is destabilizing*, by, in principle, providing invaders with the ability to sustain fire support while advancing onto enemy soil, while offering lesser benefits to defenders relative to towed or static artillery.

c. *Towed artillery is stabilizing*, by, in principle, reducing the invader's ability to sustain fire support while advancing onto enemy soil, while reducing defensive fire support effectiveness to a lesser degree.

d. *Long range surface-to-surface missiles are destabilizing*, by, in principle, enabling an attacker to destroy targets deep on the defender's soil without first breaking through the defender's forward forces.

e. *Short range surface-to-surface missiles are stabilizing*, by, in principle, increasing local defenders' ability to employ indirect fires from covered positions.

4.2.3.4 Counter-Mobility Capabilities

115. It could be hypothesized that:

a. *Counter-mobility capability is stabilizing*, by, in principle, reducing the tempo of offensive operations and increasing the combat effectiveness of defending forces.

4.2.3.5 Obstacle Breaching and Crossing Capabilities

116. It could be hypothesized that:

a. *Assault bridging capability is destabilizing*, by, in principle, increasing the ability of attackers to conduct opposed river crossings.

b. *Assault breaching capability is destabilizing*, by, in principle, increasing the tempo of offensive operations through defensive barriers and decreasing the combat effectiveness of defending forces.

4.2.3.6 Air Defense Capabilities of Land Forces

117. It could be hypothesized that:

a. *Static/low mobility ground based air defense systems are stabilizing*, by, in principle, enabling stationary defenders to protect themselves against air attack while preventing mobile invaders from extending ground based air defense coverage over an advance into enemy territory.

b. *Mobile ground based air defense systems are destabilizing*, by, in principle, enabling mobile invaders to extend ground based air defense coverage over an advance into enemy territory while offering lesser benefits to stationary defenders.

4.2.3.7 Air Mobility/Mechanization of Land Forces

118. It could be hypothesized that:

a. *Tactical air mobility is stabilizing*, by, in principle, enabling faster defensive counterconcentration.

b. *Strategic air mobility is destabilizing*, by, in principle, reducing defensive warning time of an offensive buildup of forces in a theater of operations.

c. *Mechanization of land forces is destabilizing*, by, in principle, providing attackers with the combination of mobility and armor protection necessary to advance under fire.

d. *Motorization of land forces is stabilizing*, by, in principle, providing defenders with thin-skinned, wheeled mobility useful for counterconcentration in the rear without providing the armor protection necessary for mobility under fire.

4.2.3.8 Battlefield Ground Attack Air Capabilities[2]

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[2] I.e., close air support (CAS) and battlefield air interdiction (BAI).

119. It could be hypothesized that:

a. *CAS is stabilizing*, by, in principle, enabling defenders to counterconcentrate airborne firepower rather than (slower moving) ground forces.

b. *Battlefield air interdiction is destabilizing*, by, in principle, enabling invaders to interfere with counterconcentration of defensive forces through air attacks against moving columns deep in the defensive rear.

4.2.3.9 Offensive Counter Air Capabilities

120. It could be hypothesized that:

a. *Offensive counter air capabilities are destabilizing*, by, in principle, creating incentives for preemptive attack.

4.2.3.10 Deep Interdiction Capabilities

121. It could be hypothesized that:

a. *Deep interdiction capabilities are destabilizing*, by, in principle, enabling invaders to interfere with counterconcentration of defensive forces through air attacks against moving columns deep in the defensive rear, and to threaten targets deep in the defender's territory without first defeating the forward defenses.

4.2.3.11 Defensive Counter Air Capabilities

122. It could be hypothesized that:

a. *Short range defensive counter air capabilities are stabilizing*, by, in principle, providing cover against offensive ground attack aircraft.

b. *Long range defensive counter air capabilities (e.g., fighter escorts for deep strike raids) are destabilizing*, by, in principle, increasing the effectiveness of offensive deep strike aircraft.

4.2.4 Hypotheses Relating to Factors Specific to Certain Parties

123. Factors specific to certain parties and relevant to military stability include maritime power projection capabilities; amphibious capabilities; and special operations capabilities.

4.2.4.1 Maritime Power Projection Capabilities

124. It could be hypothesized that:

a. *Maritime power projection capabilities are destabilizing*, by, in principle, enabling an invader to conduct offensive operations against defenders not contiguous to the invader's territory.

4.2.4.2 Amphibious Capabilities

125. It could be hypothesized that:

a. *Amphibious capabilities are destabilizing*, by, in principle, enabling an invader to conduct offensive operations against defenders not contiguous to the invader's territory, or to land offensive forces along coastlines in the defender's rear.

4.2.4.3 Special Operations Capabilities

126. It could be hypothesized that:

a. *Special operations capabilities are destabilizing*, by, in principle, enabling an invader to insert forces deep in the defender's rear, disrupting defensive counterconcentration and/or threatening targets deep in the defender's territory without first defeating the forward defenses.

4.2.5 Hypotheses Relating to the Nature of the International System

127. Properties of the international system relevant to military stability include its polarity and the patterns of alignment among states.

4.2.5.1 Polarity

128. It could be hypothesized that:

a. *Bipolarity is stabilizing*, by, in principle, simplifying accurate balance assessment by the two principle parties, reducing opportunities for buck-passing, and thereby increasing the likelihood of appropriate balancing responses to offensive buildups by either party.

b. *Multipolarity is destabilizing*,[3] by, in principle, creating opportunities for the construction of large offensive "bandwagoning" coalitions, complicating accurate balance assessment and encouraging buck-passing by threatened states, and thereby reducing the likelihood of appropriate balancing responses to dangerous accumulations of offensive power.

[3] And by extension, the larger the number of poles in a multipolar system, the less stable the system.

c. *A high degree of distinguishability is required for stability in a multipolar system with many poles*, as, in principle, only the adoption of forces visibly incapable of attack can provide assurance to all states in the system that no coalition of opponents will amass military power sufficient to invade successfully.

d. *A high degree of "defensive advantage" is required for stability in a multipolar system with many poles*, as, in principle, only if all states' forces are much more effective on the defensive than on the offensive can all states in the system be assured that no coalition of opponents will amass military power sufficient to invade successfully.

4.2.5.2 Alignment

129. It could be hypothesized that:

a. *Rigid alliance systems are destabilizing*, as, in principle, they may escalate disputes between pairs or small groups of states into systemic wars between opposing blocks.

4.2.6 Hypotheses Relating to the Nature of Domestic Political, Economic, or Social Structures[4]

130. Properties of domestic political, economic, or social structures relevant to military stability include the nature of governing regimes, or civil-military relations within states.

4.2.6.1 Regime Type

131. It could be hypothesized that:

a. *Democracy is stabilizing*, as, in principle, the openness (and other properties) of democratic governance makes democratic states less war-prone, and particularly, less prone to attack other democracies.

b. *Democracy is destabilizing*, as, in principle, the openness of negotiations conducted by democratic governments may make concessions more difficult.

4.2.6.2 Civil-Military Relations

132. It could be hypothesized that:

[4] Domestic political, economic, or social structures are listed here for illustrative purposes only. Although relevant to stability in a broad sense, hypotheses relating to the nature of domestic political, economic, or social structures are beyond the scope of the RSG and will not be explicitly considered.

a. *Conflictual civil-military relations are destabilizing*, as, in principle, military organizations threatened by excessive civilian intervention may overemphasize offensive operations and exaggerate external threats in order to preserve organizational autonomy; alternatively, excessive military intervention in civilian governance may encourage militarism and aggressive national foreign policies.

b. *Conflictual civil-military relations are stabilizing*, as, in principle, regimes uncertain of the loyalty of their military establishments may be more reluctant to go to war.

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CHAPTER 5

TESTS OF HYPOTHESES

5.1 GENERAL

133. This chapter describes the results of the simulation experiments conducted to test key hypotheses taken from the list in chapter four. As the complete list is too extensive for exhaustive testing here, a subset was selected for detailed examination. The selection of this subset was based both on its perceived importance for the problem of stability, and on the availability of appropriate national simulation models and existing analytical results. While many interesting hypotheses remain to be tested, the RSG nevertheless believes that the selected subset represents both a particularly important group, and one of sufficient size and diversity to permit meaningful conclusions to be drawn.

134. The experiments were structured as attempts to falsify particular hypotheses. If the results of a given test failed to falsify, this was taken as evidence tending to corroborate the hypothesis. Of course, no experiment can ever conclusively prove, or validate, a proposition; the most that can be done is provisionally to fail to falsify it. Nevertheless, to sustain an hypothesis against a challenging test (that is, an aggressive attempt to falsify it) is to permit increased confidence in that hypothesis pending further testing -- and the more challenging the test, the greater the confidence warranted by the results.

135. To provide challenging tests of hypotheses relating to stability, a number of conditions had to be met. First, for tests of hypotheses regarding weapon types, the use of that weapon had to be two-sided. That is, both the attacker and the defender had to be given comparable access to the weapon. Without this, it would only be possible to assess whether a weapon was effective or not in a single role; to determine whether it was *stabilizing* (rather than merely effective per se) it is necessary to determine the net influence of its effectiveness on the attack *and* on the defense.

136. Second, for tests of hypotheses regarding weapon types or force levels, the experimental design had to ensure that the weapons or forces were employed in their best possible use for the prevailing circumstances. That is, both attacker and defender must employ the resources at their disposal to their maximum military potential. To conclude, for example, that attack helicopters were stabilizing based on their inability to assault a dug-in defense would be misleading if the best use of such weapons were to bypass forward prepared positions and ambush moving vehicle columns in the opposing rear area. To base stability

conclusions on less than the best-possible uses of weapons or forces would be to risk unanticipated instability should a resourceful military organization discover a better use for an asset than the one considered in the simulation testing.

137. Finally, the experimental results are strengthened to the degree that the experimental design is conservative with respect to the results obtained. For example, if an hypothesis implies that infantry cannot attack successfully, a falsification would be strongest if it took the form of a successful infantry attack conducted under conditions normally thought unfavorable for offensive infantry operations (such as daylight, or open terrain). Conversely, the falsification would be weakest if it consisted of a successful attack conducted under conditions uniquely well-suited to offensive infantry operations (such as night, bad weather, or heavily forested terrain).

5.2 SIMULATION RESULTS

138. The simulation experiments were conducted in four sets, using four national models: a test of hypotheses regarding the stability properties of infantry using the U.S. Janus model; a test of hypotheses regarding the stability properties of decoys using the Danish SUBSIM model; a test of hypotheses regarding the stability properties of air mobility using the German TRIAMOS model; and tests of several hypotheses regarding the stability properties of tanks, infantry, artillery, air defenses, force levels, doctrine, and terrain using the German KOSMOS model.

5.2.1 Janus Experiments

139. The Janus experiments (see Annex IV, Appendix 2 for a detailed description) were designed to test hypothesis 4.2.3.2.a: that infantry is stabilizing because it cannot successfully assault a defended position.

5.2.1.1 Scenario and Experimental Design

140. If hypothesis 4.2.3.2.a were true, we would expect to observe increasing attacker casualties as less armor-heavy forces are introduced on both sides. Moreover, the hypothesis implies that it should be impossible to construct a successful attack with a pure infantry force. To test this hypothesis thus requires a series of experiments with variance in

the infantry content of the attacking and defending forces, and including at least one "pure" infantry attack force.[5]

141. The scenarios for the test pitted a Soviet-style motorized rifle regiment (three motorized rifle battalions and a tank battalion) in the attack against a defending United States-style force consisting of two mechanized companies and a tank company, supported by anti-armor missile equipped vehicles. In the base case, the attacker did not dismount his infantry from their infantry fighting vehicles, choosing instead to maximize assault velocity.

142. Three excursions involved progressively lighter (that is, more infantry-heavy), forces on both sides. In each excursion, the attacker's infantry dismounted for the assault. In the first excursion, all tanks were replaced with infantry fighting vehicles. In the second excursion, all tanks and infantry fighting vehicles were replaced with lighter, armored personnel carriers mounting .50 caliber machine guns for direct fire support. In the final excursion, all tanks, infantry fighting vehicles, or armored personnel carriers were replaced with five-ton transport trucks equipped with .50 caliber machine guns. As the forces became lighter, the attacker's artillery preparation became heavier: a 25-minute artillery preparation preceded the attack in the base case, which was increased to one hour in the IFV case, two hours in the APC case, and three hours in the Truck case.

143. In all four cases examined, the defender's forces were deployed to provide the best lines of sight and fields of fire possible. Moreover, the defender's vehicles were dug in to hull defilade, while dismounted infantry were deployed in fully prepared foxholes, exposing themselves only to fire their weapons. To further complicate the attacker's assault, and to make a more challenging test of the hypothesis, the assault took place in daylight, during clear weather, and was launched across an open, flat river-bed plain, with little or no vegetation available for cover.

144. To control for extraneous variables, both attacker and defender were equipped with Soviet-style vehicles and US-style weapons. Infantry fighting vehicles, armored personnel carriers, and trucks were all provided with identical eight-man infantry squads. The initial, attacker:defender force ratio in all four cases was three to one, scored in armored fighting vehicle equivalents (or "AFVEs:" for a description, see Annex IV, Appendix 2).

5.2.1.2 Findings

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[5] We will assume here that the "purest" realistic infantry force is one consisting of foot soldiers transported by wheeled, unarmored vehicles. Although the "purest" *theoretical* infantry force might be one consisting solely of walking foot soldiers, the ubiquitous availability of motor transport in modern economies makes this a highly unlikely form of military organization -- even if a combatant adopted such an organization in peacetime, its forces could readily be equipped with civilian transport in time of war.

145. The simulation results suggest that infantry forces *can* successfully attack a defended position. The percentage of the attacker's losses when APCs or trucks were employed were not greater than his losses in the more armor-heavy base case. As both attacker and defender lightened their forces, the attacker's ability to carry out a successful assault did not diminish. The attacker did, however, slow down the velocity of his attack as the forces became less armor-heavy, with a 4.5-hour increase in the time required to complete the attack in the truck case versus the base case. While there is no evidence that such a delay would be decisive for the success of the theater attack as a whole, the effect of such a velocity reduction warrants further analysis. Overall, though, the results obtained tend to disconfirm the hypothesis -- and to do so strongly, given the highly infantry-unfavorable nature of the terrain and weather conditions assumed here.

5.2.2 SUBSIM Experiments

146. The SUBSIM experiments (see Annex IV, Appendix 1 for a detailed description) were designed to test hypothesis 4.2.2.5.g: that cover, concealment and camouflage capabilities are stabilizing, by, in principle, increasing the combat effectiveness of stationary defenders (who can more fully exploit the potential of cover, concealment and camouflage than can moving attackers).

5.2.2.1 Scenario and Experimental Design

147. The base case is a battalion sized attack force against a company sized defense force. The battle takes place in a relatively flat area situated in the northern part of Germany. The attack consists of 18 attacking APCs advancing toward a defense line and of 9 tanks, which are tasked to give supporting fire to the attacking APCs. The defense consists of 9 tanks. The defending tanks fight from prepared positions. The supporting tanks of the attacker will remain in their hull down positions during the move of the APCs.

148. To evaluate the effect of tank decoys, the base case was modified by replacing three tanks with six tank decoys. Each of the tanks operates in conjunction with a decoy. When a defending tank moves into a hull down position, the corresponding decoy becomes exposed. The decoys of the attacker are exposed like the attacking tanks.

149. The (tank) decoys are in hull down positions similar to real units. The shape of a decoy is identical to the shape of a real unit. The decoy is active, producing similar flash and smoke trails as the fire of the real units. The decoys are semi-static; they have a pop-up/pop-down ability; but they are not moved during the battle.

150. Three variations on the base case were conducted. In the first variation, both the defender and the attacker replace 3 tanks with 6 decoys. In the second variation only the

defender replaces tanks with decoys, and in the third variation only the attacker performs the replacement.

5.2.2.2 Findings

151. The use of decoys increases the military capability of the defending and attacking units. The decoys are semi-static with a pop-up/pop-down ability and can produce flash and smoke trails like a real unit. The simulation experiments show that the defender and the attacker may gain approximately equally if both parties may use decoys. The ability to deploy decoys effectively may, however, be different for the defender and the attacker. A defense from prepared positions will make it possible to prepare the insertion of decoys in such a way that the resemblance to real units is adequate. Only in few cases would it be possible for the attacking unit to deploy decoys unexplored by defending units. Therefore, it is expected that the defense will be able to employ decoys effectively in more cases than the attack, at least at the tactical level.

152.. The great advantage of employing decoys and the greater possibilities for the defense to do so indicates that employment of decoys should enhance stability at the tactical level. At the theater level, where both the invader and the invaded may conduct some tactically offensive and some tactically defensive combat actions, the net effect of increased decoy availability to both sides is less clear.

5.2.3 TRIAMOS Experiments

153. The TRIAMOS experiments (see Annex IV, Appendix 4 for a detailed description) were designed to test hypothesis 4.2.3.7.a: that tactical air mobility is stabilizing, by, in principle, enabling faster defensive counterconcentration.

5.2.3.1 Scenario and Experimental Design

154. The experiments considered air mobility of two kinds: air mobile infantry (which was considered only in the defense), and attack helicopters. While the asymmetry of the experiments makes interpretation of the results more complex than would a symmetric design (and in particular, makes direct falsification problematic), in exchange it offers a broader consideration of the stability issues associated with air mobility than would a narrower, purely symmetric approach.

155. In the (corps level) scenario, the attacker's ground forces consisted of seven tank and mechanized infantry divisions, two of them being operational reserves. The attack was executed along three axes, with the main attack in the center and a flank attack by one tank division in the north.

156. The defender's forces consisted of two airborne infantry divisions, tasked to delay and block the attacker in the center and in the south, one tank division for counter attack into the southern flank of the attacker, and one tank brigade to block and disrupt the surprise flank attack of a tank division.

157. Combat support forces were deployed on both sides. In particular, the attacker's attack helicopter companies conducted CAS and BAI missions and scattered minefields. CAS means that attack helicopters supported ground forces engaged with opposite ground forces, while BAI denotes the interception role of attack helicopters against forces on the march or on approach. Air attack forces delivered CAS and/or BAI type sorties against opposite ground forces.

158. Thirteen simulation runs with TRIAMOS were performed. The base case is compared with excursion cases in which helicopter and air attack missions on both sides have been varied. The variations have been restricted to the flank attack/defense area of the scenario. This helped to circumvent structural variance problems in the evaluation process and allowed measurement of the impact of the varied air assets in a controlled manner.

5.2.3.2 Findings

159. The two airborne infantry divisions were able to delay, screen out. and finally block the main attack, and to create a situation in which the defender's tank division could successfully counterstrike. Assuming that the defender's build-up of the main forces in time for delaying and blocking the attacker was only possible with airborne assets, there is thus some indication that tactical and operational heli-based forces might contribute to stability, although in the absence of a two-sided assessment only partial conclusions can be reached. Additional helicopter missions on the defender's side may also result in valuable time gains for the ground defense, which could be used to improve defense preparations and/or to bring additional forces into their position. This could also have a stabilizing effect, although again the results do not permit a definitive conclusion.

160. On the attacker's side, additional helicopter missions caused earlier disruption of the defense and increased the danger of envelopment. And if both sides reinforce their ground forces by attack helicopter units of similar strength, there is some indication that this would turn out to be in favor of the attacker, because he is able to preserve a favorable force ratio over a longer period of time -- although again these results must be regarded as preliminary in nature.

161. On balance, then, valuable applications of air mobility were identified for both attackers and defenders in the scenario considered. Although it cannot yet be definitively determined whether the offensive applications were relatively more or relatively less valuable

than the defensive when applied simultaneously, this nevertheless suggests that air mobility is at least unlikely to be either purely defensive or purely offensive in nature.

5.2.4 KOSMOS Experiments

162. The KOSMOS experiments (see Annex IV, Appendix 3 for a detailed description) were designed to test the following hypotheses:

- 4.2.1.1.d: that doctrines emphasizing rapid closure with the enemy are destabilizing, by, in principle, reducing the reaction time available to defenders prior to offensive breakthrough

- 4.2.2.5.g: that cover, concealment and camouflage capabilities are stabilizing, by, in principle, increasing the combat effectiveness of stationary defenders

- 4.2.1.3.a: that close terrain is stabilizing, by, in principle, increasing the availability of defensive cover, facilitating the construction of defensive obstacles, and slowing the tempo of offensive operations

- 4.2.1.5.a: that high force-to-force ratios are destabilizing, by, in principle, enabling invaders to overwhelm smaller defending forces

- 4.2.1.5.b: that low force-to-space ratios are destabilizing, by, in principle, stretching defensive forces too thinly to resist in sufficient numbers at any single point, and/or creating opportunities for more offense-favorable non-linear, maneuver warfare methods

- 4.2.3.1.a: that tanks are destabilizing, by, in principle, providing mobile, protected firepower essential for advancing under fire

- 4.2.3.2.a-e: that infantry is stabilizing

- 4.2.3.3.a: that artillery is stabilizing, by, in principle, enabling defenders to counterconcentrate by fire rather by the (slower) movement of ground forces.

5.2.4. Scenario and Experimental Design

163. In all scenarios one division attacks one brigade. In some scenarios, the defender's brigade is flanked by two brigades (in order to prevent an encirclement or a flank attack). However, in the experiments the flanking brigades do not support the center brigade directly other than through artillery fire.

164. Variations are made on terrain type, visibility, degree of defense preparation, unit structures of defender and attacker, force-to-force ratios, and force-to-space ratios.

165. On the defenders side, three battalions fight next to each other, each being assigned a sector of 5 km width. They are deployed to forward positions. The combat support systems are deployed behind the front battalions. The reserves wait in their assembly areas.

166. The attacking division tries to break through the brigade's defenses. The attack is organized in two echelons. The first echelon consists of two brigades attacking side by side and being reinforced by available divisional troops (e.g., additional artillery). The second echelon is made up of the third brigade attacking along the routes of the more successful of the two first echelon brigades. Each attacking brigade deploys three battalions as front battalions and the remaining one as a reserve. The combat support systems follow immediately behind the front battalions.

167. All combat and combat support units are controlled by a rule system adapting their actions and reactions to the (perceived) situation (see chapter 3.4 of Annex IV.3).

5.2.4.2 Findings

168. Regarding the hypothesis that doctrines emphasizing rapid closure with the enemy are destabilizing, in all experiments a high degree of defense preparation turned out to be stabilizing (see Fig. 5.11 in Annex IV.3). Doctrines emphasizing rapid closure with the enemy result in less time being available for defense preparation, i.e., in a deliberate or hasty defense, and thus appear destabilizing.

169. Regarding the hypothesis that cover, concealment and camouflage capabilities are stabilizing, inasmuch as these are important elements of defensive preparation, and inasmuch as the experiments suggest that defensive preparation is stabilizing, cover, concealment and camouflage would thus be stabilizing as well. By the same token, however, it should be pointed out that camouflage capabilities on the attacker's side may have *destabilizing* effects. Especially in a low density battlefield it is extremely important that the attacker is detected early enough, and effective attacker camouflage can make this more difficult. Overall, then, the experimental results were thus inconclusive.

170. The hypothesis that close terrain is stabilizing was partly falsified by our experiments of the third and fourth series. Depending on the type of attacker and defender, the effects of terrain change, and sometimes even switch. In particular, as can be seen from table 5.3 a/b in Annex IV.3, close terrain favors the defender only when infantry-heavy, and open

terrain favors the defender only when tank-heavy. In both cases, the effects are reinforced the more tank-heavy the attacker is. Thus, whether close terrain is stabilizing or destabilizing depends on the type, structure, and posture of the units involved, as well as on the value of other situational parameters.

171. The hypothesis that high force-to-force ratios are destabilizing was strongly supported by the KOSMOS experiments. In all cases the ASP estimates increase monotonically with the attacker:defender force ratio.

172. The hypothesis that low force-to-space ratios are destabilizing was only partially supported by the experimental results. In particular, these results suggest that low force-to-space ratios are only destabilizing when the defender was not able to react quickly enough, e.g., when the attack velocity was too high. In experiments where the defender was able to react in time and did employ his forces correctly, low force-to-space ratios were stabilizing (see the remark on the stability properties of camouflage). This is depicted by the dotted curves presenting the low force-to-space ratios in figure 5.1 and 5.3. On the other hand, in these experiments the force-to-space ratios were decreased on the attacker's as well as on the defender's side. It could be hypothesized that an attacker will seldom use low force-to-space ratios but will prefer to cover a smaller terrain with its troops instead. In any case, further simulation experiments on this topic are required. Overall, then, on a thinned out battlefield the capability for immediate defensive response to offensive actions is extremely important for stability, i.e., the time and place of the attack must be anticipated in time to reach prepared defense positions before the attacker arrives there. Therefore timely tactical intelligence is very important for a thinned-out defense.

173. Regarding the hypotheses that tanks are destabilizing while infantry and artillery are stabilizing, the simulation experiments suggested that no weapon systems or combat units among those investigated are defensive or offensive under all circumstances.

174. In particular, there is no evidence that tanks favor the attacker while infantry favors the defender. Infantry seems to be quite capable of offensive operations in rough terrain, under poor visibility conditions, while tanks represent a formidable defensive system, especially in open terrain under good visibility conditions.

175. The stability properties of artillery also depend on situational conditions, particularly the vulnerability of the targets. Artillery proved stabilizing only where there was a significant defender advantage, such as more accurately directed fire and lower vulnerability of defending artillery systems. By contrast, where rocket artillery was used to deploy scatterable mines, artillery use favored the attacker rather than the defender. This was because the mines delayed the movement of the defender's reserves, preventing them from becoming available in time to be of any significant benefit.

176. In any case, it should be kept in mind, that -- under thinned out battlefield conditions and following a flexible and mobile defense doctrine (e.g., rapid reaction and counter concentration) -- all options having stabilizing effects by decreasing the options of the attacker may also be used to weaken the defender, especially when he has not reached his defense positions.

177. In addition, the simulation results also have implications for some hypotheses that were not explicitly tested.

178. Hypothesis 4.2.1.1.b, for example, holds that doctrines emphasizing large mobile reserves are stabilizing; as the availability of large mobile reserves favored the defender in the KOSMOS experiments, the simulation results thus tend to corroborate.

179. Hypothesis 4.2.2.5.a holds that surveillance capabilities are stabilizing; inasmuch as the experiments showed the importance of timely defensive perception of the attacker's direction, the results thus tend to corroborate.

180. Hypothesis 4.2.3.4.a holds that counter-mobility capabilities are stabilizing; the simulation results suggest that this is true only when troops are necessary to man or overwatch the counter-mobility system. If, for example, the counter-mobility system is delivered remotely by long range rocket artillery, then the result favors the attacker rather than the defender.

181. Finally, hypothesis 4.2.3.6.a holds that static or low mobility ground based air defense systems are stabilizing; the simulation results tend to corroborate this proposition (see the discussion under section 7.2.2.5, "Helicopters/Air Defense," below).

CHAPTER 6

ASSESSMENT OF REGIONAL MULTIPOLAR STABILITY

6.1 THE STABLE REGIONAL FORCE RATIO MODEL

182. In order to facilitate the assessment of military stability in a multipolar context, an analytical model is proposed that compares the combat power of the force postures of potential conflict parties in a given region in the light of so-called *stable regional force ratios* (SRFR). It is meant to fill the gap between the simple *static methods* of analysis, used extensively for estimating, in quantitative terms, the overall *unilateral* capability of military forces, and the *dynamic methods* which comprise more or less complex models for simulating military conflicts or battles between two parties for the sake of arriving at force or unit capability measures vis-à-vis a specific opponent, i.e., for estimating *bilateral* capabilities.

183. The underlying concept implies that, independent of mutual force levels, a ratio can be determined, between the *offensive* combat power available from the military forces of a potential aggressor party in the respective region and the *defensive combat power* of the military forces of the victim party, at and below which the latter considers the military situation vis-à-vis the former as stable in the sense that it feels secure from attack. This ratio, the SRFR, is identical to the inverse of the *relative operational minimum of the defense*, i.e., the minimal defensive combat power that, for the sake of credible deterrence, the victim must have relative to the offensive combat power available to an aggressor.

184. In addition to size and topographical characteristics of the respective theater of operations, the SRFR captures the operational objectives and concepts of both, aggressor and victim, their risk attitudes, the relative mobility of their forces, the tactical warning available to the victim and the tactical level criteria for repelling attacks. Thus, in contrast to the traditional methods of static analysis, the SRFR-concept permits accounting for important qualitative factors of military capability as well as for the nature of non-military relations between parties and their security requirements.

185. Figure 6.1 shows the macrostructure of the SRFR-concept for the assessment of regional multipolar military stability, illustrating how it links static methods for estimating the offensive and defensive combat power of military forces and dynamic tools for providing tactical level success criteria. The SRFR-model comprises two principal submodels, the multipolar stability model ASAM and the model GEFRAM for estimating the SRFR.

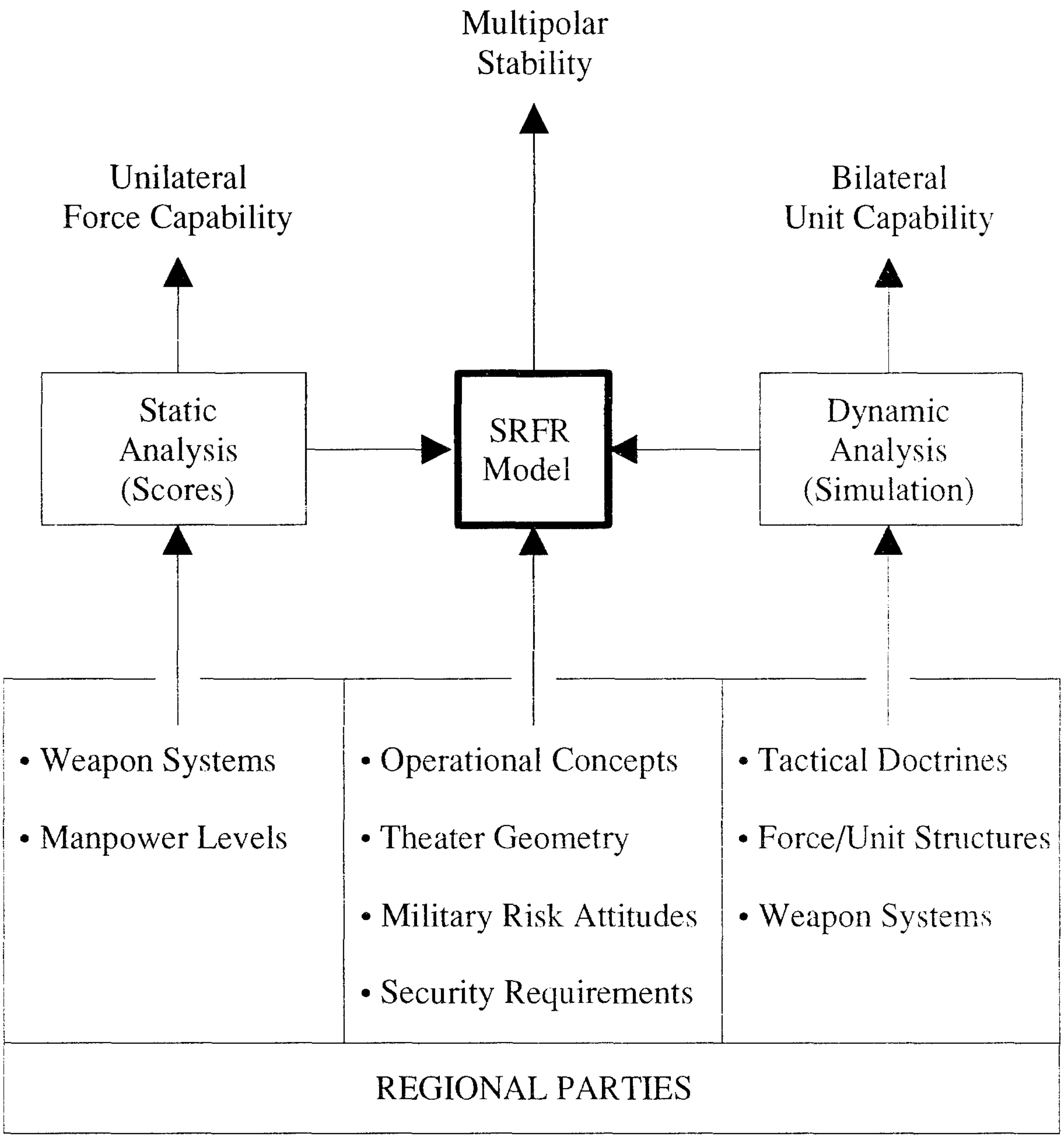

Figure 6.1: Macrostructure of the Stable Regional Force Ratio (SRFR)-concept for the assessment of regional multipolar military stability

6.1.1 Stability Criteria

186. The nature of non-military relations between parties, their security requirements, and their military risk attitudes are captured by the stability criteria adopted by the regional parties. According to the conceptual model discussed in chapter 2.2.1, a given party may assess the nature of non-military relations with other parties in terms of subjective probabilities that the other parties harbor *hostile intentions* in the sense that they would consider aggression in case of a crisis. However, even if a party is regarded as being hostile, it is by no means certain that it would consider as acceptable the *military risk* associated with an aggression. In fact, a given party may feel quite secure vis-à-vis a hostile party if there is sufficient evidence that the latter's risk aversion is high. If there is not, the respective party still need not feel threatened if it could be reasonably certain that it had the military capability for repelling an aggression.

187. It goes without saying that, unless there is a proven record that settling conflicts between parties by military means is altogether out-of-question , there is no way for a party to know for certain the degree to which the intentions of other parties may become hostile eventually. This is also true for the military risk attitude of parties that have no established record of military risk aversion. However, with a view to the probability values for the absence of war that political elites usually associate with *stability* (i.e., at least 90 percent), it can be shown that there is no need for an assessment of intentions and military risk attitudes of other parties other than specifying whether their intentions can be considered to be strictly peaceful or not, and whether their military risk aversion is *demonstrably* high or not.

188. If intentions of a party may be regarded as strictly peaceful, military stability is irrelevant for the security vis-à-vis the respective party. If not, i.e., if there is uncertainty about the intentions, there are essentially two criteria that are of practical relevance for the assessment of military stability: the *sufficiency* criterion and the *security* criterion (see also chapter 3.3).

189. The *sufficiency* criterion is appropriate either if military history indicates that the party in question is traditionally *risk averse*, or if there is reason to assume that it would not jeopardize good non-military relations with a potential victim of aggression unless being rather certain of success when attacking. Thus, in both cases a stable situation would be characterized by high threshold values for the probability of attack success (e.g., 90 percent or more).

190. The *security* criterion is appropriate if the potential aggressor cannot be regarded as being risk-averse and non-military relations with the victim are less than cordial so that an eventual aggression cannot be discounted. In this case, the victim would feel secure

only if the probability for being able to repel an aggression is sufficiently high (e.g., more than 90 percent).

6.1.2 The Multipolar Stability Model ASAM

191. The multipolar stability model ASAM assumes that a given party k feels secure, if the defensive combat power N_{DK} available from its force posture is equal to or higher than the minimal defensive combat power N_{DKmin} required for deterring or repelling simultaneous attacks by all parties $i \neq k$ which may join an offensive coalition against party k. If that is the case for each party $k = 1,...,n$ in the respective region, the region is considered to be militarily stable. In other words, multipolar stability requires that each party in the region needs to have sufficient defensive combat power so that the values F_{ki} of the SRFR are not exceeded vis-à-vis all parties $i \neq k$ belonging to an offensive coalition against party k.

192. Thus, regional military stability exists if the following mathematical relation is satisfied:

$$\bar{N}_{Dk} \geq N_{Dk\,min} \; \forall \; k = 1, ..., n \tag{6.1}$$

with

$$N_{Dk\,min} = \sum_{i \neq k \in T_k} \frac{N_{Ai}}{F_{ki}} \tag{6.2}$$

and

$$\bar{N}_{Dk} = N_{Dk} + \sum_{i \neq k \in D_k} f_{ik} \cdot N_{Di} \tag{6.3}$$

and the notations given below:

i = index of regional parties ($i = 1,...,n$)

k = index of victim party ($k = 1,...,n$)

n = number of regional parties

N_{Dk} = defensive combat power of party k

N_{Ai} = offensive combat power of party i

F_{ki} = stable regional force ratio (SRFR) for party k vis-à-vis party i

T_k = subset of parties $i \neq k$ that may join an offensive coalition against party k

D_k = subset of parties $i \neq k$ that support the defense of party k

f_{ik} = fraction of defensive combat power of party i earmarked for the defense of party k.

193. If the victim party under consideration cannot expect to be supported in its defense by other parties ($f_{ik} = 0 \; \forall \, i \neq k$), the overall defensive combat power N_{Dk} available to party k is equal to the defensive combat power N_{Dk} of its own military forces, i.e., (6.1) modifies to

$$N_{Dk} \geq N_{Dk\,min} \; \forall \; k = 1, \ldots, n \tag{6.4}$$

194. Multipolar military stability requires that the difference (N_{Dk} - N_{Dkmin}) between the available defensive combat power and the minimal defensive combat power required for deterrence is positive, or at least zero, for all parties k = 1,..., n of the regional international system in question. Otherwise, the situation would be unstable in the sense that the stability criteria underlying the SRFR are not met for the respective parties k because of a deficit in defensive combat power.

6.1.2.1 Principal Options for Improving Stability

195. Eq. (6.2) and (6.3) indicate that there are essentially four options for the reduction or elimination of a defensive deficit of party k:

a. Reduction of the offensive combat power N_{Ai} of the parties $i \neq k \in T_k$ *(arms control option);*

b. Increasing the SRFR-values F_{ki} *(defense improvement option);*

c. Increasing the defensive combat power N_{Dk} of party k without a significant increase in its offensive combat power N_{Ak} *(non-offensive defense option);*

d. Availability of additional defensive combat power from third parties $i \neq k \in D_k$ *(collective defense option).*

196. The first option may be called the *arms control option.* It requires reductions of the numbers of weapon systems and equipment essential for offensive operations, and of active duty personnel, that the various parties may maintain in the respective region. However, there are limitations to the arms control option because the reduction of a party's offensive capability is inevitably accompanied by a reduction of its defensive capability. Thus, reductions aimed at reducing offensive combat power may actually worsen existing deficits in a party's defensive combat power and thus become destabilizing.

197. Whether or not multipolar stability is attainable merely from exercising the arms control option depends primarily on the ratio of the defensive and offensive combat power available from the force postures of the parties, i.e., their "defensiveness", and on the number of parties in the region. The higher the defensiveness of the force postures and the lower the number of regional parties the easier it would be to approach a stable situation through reductions of weapon systems and personnel ceilings. In any case, exercising this option requires rules that distribute inevitable deficits in defensive combat power in a "fair" manner among the regional parties. Thus, it is a *multilateral* option that requires agreement among all parties involved.

198. The second option, of increasing the stable regional force ratio, may be called the *defense improvement option* . It involves technical, structural, and operational/tactical measures that improve the defensive effectiveness of military forces. These include the development of efficient defense doctrines and the training of officers and soldiers in defensive operations and tactics. They may be implemented *unilaterally* without detrimental effects for regional stability, at least as long as measures intended for improving the defensive effectiveness do not result in a simultaneous increase in offensive combat power that would reduce the "defensiveness" of the respective forces.

199. With a view to the principal limitations of the arms control option in a multipolar context, regional military stability may depend on the additional implementation of defense improvements by the regional parties, especially by the weaker ones. Therefor, it would be in the interest of all parties that appropriate military assistance programs be devised for and extended to those parties lacking the means and/or skills for implementing defense improvements.

200. The adoption of the third option, of increasing the defensive combat power of military forces without increasing their defensive combat power, depends on the availability of so-called Non-Offensive-Defense (NOD) systems which are distinguished by a high degree of defensive but little or no offensive effectiveness. If such systems were feasible and more cost-effective in defensive operations than the traditional multipurpose systems, there would be no reason for *status quo*-oriented parties not to replace the traditional systems by NOD-systems.

In fact, the availability of highly cost-effective NOD-type systems would almost necessarily result in the evolution of ultra-stable international systems, provided that all parties in the respective region are truely *status quo*-oriented. In such systems, no party retains any offensive capabilities other than limited contributions to multinational units required for out-of-region or out-of-area intervention operations.

201. It is an undisputed tenet of political theory that distinguishable NOD-type force postures are an indispensable prerequisite for eliminating the so-called *security dilemma* and, in conjunction with a higher defensive effectiveness, for a world devoid of arms races and crisis instability. Unfortunately, as of today there seems to be no convincing evidence that efficient NOD-systems are not merely theoretical constructs but practically feasible, at least not in the short or medium term. But even if they were, due to budgetary constraints the conversion of traditional military forces into NOD-type forces would be a long-term project at best.

202. The fourth and last option, of making up for regional deficits in defensive combat power through a timely import of defense forces by third parties, may be implemented in several ways such as, e.g., by integrating the deficient parties into existing defensive alliances, by the creation of new defensive alliances, or by the ad-hoc formation of defensive coalitions if a threat materializes, and through the extension of formal security guarantees or credible assurances. Lastly, all of these options boil down to some form of *collective defense.*

6.1.2.2 Dynamic Stability Requirements

203. It goes without saying that the multipolar stability conditions (6.1) and (6.4) must be satisfied at any given point in time. Thus, in order to account for the possibility of one or more parties deciding unilaterally to increase their weapon system holdings and active duty personnel levels (i.e., to mobilize, build-up, or reconstitute their military forces), the model must be extended to include build-up rates as well as response times.

204. To this end, it is assumed that force build-ups are organized in a manner that entails a constant rate a_i at which the offensive and defensive combat power of parties i (i =1,..., n) increase from the peace time levels N_{Ai} (0) and N_{Di} (0) to their maximal levels N_{Aimax} and N_{Dimax} when the forces are fully mobilized. Thus, the offensive combat power $N_{Ai}(0) \leq N_{Ai}(t) \leq N_{Aimax}$ would increase linearly with time:

$$N_{Ai}(t) = \begin{cases} N_{Ai}(0) + a_i t & \text{for } 0 \leq t < T_{Ei} \\ N_{Ai\,max} & \text{for } T_{Ei} \leq t \leq \infty \end{cases} \tag{6.5}$$

and

$$T_{Ei} = \frac{N_{Ai\,max} - N_{Ai}(0)}{a_i} \tag{6.6}$$

In order to maintain stability, the minimal defensive combat power N_{Dkmin} (t) which must be provided by the threatened party k at time t is equal to

$$N_{Dk\,min}(t) = \sum_{i \neq k \in T_k} \frac{N_{Ai}(t)}{F_{ki}} \tag{6.7}$$

if it is assumed that all parties $i \neq k \in T_k$ in the offensive alliance threatening party k start the build-up of their forces simultaneously at time t = 0.

205. With T_{Rk} denoting the response time of party k (i.e., the time between t = 0 when the parties $i \neq k \in T_k$ start their force build-up and the time when party k initiates its responsive build-up), the defensive potential $N_{Dk}(0) \leq N_{Dk}(t) \leq N_{Dkmax}$ which party k will have built up at time t is given by

$$N_{Dk}(t) = \begin{cases} N_{Dk}(0) & \text{for } 0 \leq t \leq T_{Rk} \\ N_{Dk}(0) + a_{Ak}(t - T_{Rk}) & \text{for } T_{Rk} < t < T_{Rk} + T_{Ek} \\ N_{Dk\,max} & \text{for } T_{Rk} + T_{Ek} \leq t \leq \infty \end{cases} \tag{6.8}$$

206. The build-up of defensive combat power N_{Dk} by party k is inevitably accompanied by a proportionate build up N_{Ak} of its offensive potential. The proportionality factor r_k is assumed to be independent of force levels with

$$r_k = \frac{N_{Ak}}{N_{Dk}} \tag{6.9}$$

207. In analogy to (6.4), multipolar stability requires that the condition

$$N_{Dk}(t) \geq N_{Dkmin}(t) \ \forall \ k = 1, \ldots, n \tag{6.10}$$

is satisfied at any point *in time* $0 \leq t \leq \infty$. Otherwise, there is a deficit in defensive combat power that needs to be filled in a manner that must not be perceived as threatening by other parties in the region.

208. It follows that the additional defensive combat power N_{Rk} that is to be provided by or to party k for the sake of stability is equal to

$$N_{Rk}(t) = \begin{cases} N_{Dk\,min}(t) - N_{Dk}(t) & \text{for } \dfrac{N_{Dk}(t)}{N_{Dk\,min}(t)} < 1 \\ 0 & \text{otherwise} \end{cases} \tag{6.11}$$

Eq. (6.11) indicates that the requirements of the victim party k for additional defensive combat power may decrease over time as its military forces are built up in reaction to the build-up of the parties $i \neq k \in T_k$. It follows that the minimal additional defensive combat power that must be provided by or to party k is equal to the maximal value at any time $t \geq 0$, i.e.,

$$N_{Rk\,min} = \max_{t \geq 0} N_{Rk}(t) \tag{6.12}$$

209. Of course, it goes without saying that the additional defensive combat power $N_{Rk}(T_{Rk})$ required at time $t = T_{Rk}$ must be available to party k in peace time, i.e., prior to a crisis characterized by the beginning of force build-ups by parties $i \neq k \in T_k$ at time $t = 0$. Therefor, N_{Rk} defines the minimal defensive combat power that third parties must hold ready in peace time for the defense of party k, unless party k can provide the additional defensive combat power unilaterally, e.g., by procuring an appropriate number of NOD-type systems.

210. Whether the additional defensive potential $N_{Rk}(T_{Rk})$, that must be maintained by or for party k in peace time, is sufficient for preserving stability beyond the reaction time T_{Rk} depends on the build-up rate a_{Rk} of the additional defensive combat power. If that build-up rate is higher than the build-up rate $a^*_{Rk}(t)$ for preserving stability at any time $t > T_{Rk}$, then the additional defensive combat power to be available in peace time need not exceed $N_{Rk}(T_{Rk})$. If not (i.e., $a_{Rk} < a^*_{Rk}(t)$, the total additional peace time defensive combat power amounts to

$$N_{RPk} = N_{Rk}(T_{Rk}) + N_{Rkadd}\,, \tag{6.13}$$

with

$$N_{Rkadd} = \sum_{t > T_{Rk}} N_{Rkadd}(t) \tag{6.14}$$

as the overall additional peace time potential for covering the deficits remaining when the build-up rate is equal to a_{Rk} for $t > T_{Rk}$. $N_{Rkadd}(t)$ results as

$$N_{Rkadd}(t) = \begin{cases} (a^*_{Rk}(T_{Rk} < t \leq T_{r+1}) - a_{Rk})(T_{r+1} - T_{Rk}) & \text{for } a^*_{Rk}(t) > a_{Rk} \\ 0 & \text{otherwise} \end{cases} \tag{6.15}$$

The required (stable) build up rate is equal to

$$a^*_{Rk}(T_{Rk} < t \leq T_{r+1}) = \frac{N_{Rk\,min}(T_{r+1}) - N_{Rk\,min}(T_q)}{T_{r+1} - T_q} \tag{6.16}$$

with the index r denoting, beginning with $T_1 = T_{Rk}$, the sequence of time points $T_r > T_{RK}$ at which the build-up of forces by the parties $i \neq k \in T_k$ is terminated. This is the case when the offensive combat power of a party i reaches its maximal value N_{Aimax} at time T_{Ei} as specified by Eq. (6.6) T_q denotes the last point in time prior to T_{r+1} at which the required reactive potential had reached a maximum, i.e.,

$$N_{Rk\,min}(T_q) = \max_{i \leq j \leq r} N_{R\,min}(T_i) \tag{6.17}$$

6.1.2.3 Illustrative Example

211. Consider three parties i = 1,2,3 the peace-time forces of which have a total offensive combat power $N_{Ai}(0)$ and a proportionate defensive combat power of $N_{Di}(0) = N_{Ai}(0) : r_i$. Each party has the capability to build up its forces to a maximal combat power level equal to 2.5 times the peace-time level. For each party i, the build-up rates a_i and a_{Ri} (combat power units introduced per day) are identical.

212. The data characterizing the three force postures and their build-up rates are as follows [with T_{Ei} resulting from Eq. (6.6)]:

Party i	$N_{Ai}(0)$	N_{Aimax}	r_i	a_i	T_{Ei}
1	442	1,105	0.69	35	18.9
2	552	1,380	0.72	45	18.4
3	670	1,675	0.7	20	50.2

The values F_{ki} of the stable regional force ratio (SRFR) between victim k and threat i are assumed as

$$[F_{ki}] = \begin{bmatrix} - & 1:1 & 1.2:1 \\ 0.9:1 & - & 1.1:1 \\ 1.3:1 & 1.2:1 & - \end{bmatrix}$$

213. Table 6.1 summarizes the results obtained with these data assuming that the response time is $T_{Rk} = 10$ days for each of the three parties. Accordingly, party k would feel secure from attacks by the other two parties only, if it could be certain that, in addition to its own peace time defense potential of 641 (= 442:0.69) units, 1086 defensive combat power units were available from, say, crisis reaction forces held ready by other (outside) parties in peace time. The additional 92 units required to reach the maximal additional potential of 1178 may be generated after the build-up of parties 2 and 3 is discovered at time $T_{R1} = 10$ because all "stable" build up rates $a^*_{Rk}(t)$ are smaller than the available build-up rate $a_{Rk} = 35$.

214. For the second party k = 2, an additional defensive combat power of 904 units must be available from the peace time postures of outside parties. Due to the rather high production rate $a_2 = 45$ for the responsive build-up of the forces of party 2, there is no need for an introduction of additional defensive combat power at time $t > T_{R2} = 10$.

215. The third party k = 3 must have an additional peace-time potential of 487 defensive combat power units available in order to still feel secure at time $T_{R3} = 10$ days when it finds out about the build-ups of the first and second party. However, in the subsequent interval (10 < t 18.4) the outside potential must be built up to 788 units. This amounts to a build-up rate of 35.8 units per day, which is considerably above the capability of 20 for party k=1. Thus, an additional defensive potential of 133 units, equivalent to the difference (35.9 - 20) = 15.9 between the required and actual production rates, must be held ready in peace-time. 168 defensive combat power units of the total of 788 required from outside, must be produced at $t > T_{R3} = 10$ days.

216. Figure 6.2 shows the build-up curves for the three parties which satisfy the stability requirements of Eq. (6.7) as presented by the solid curves resulting from the build-up of the forces of the other two parties. The dashed curves indicate the build-up of the defensive combat power obtained from the respective responding party's own forces. The dotted curves present the difference between the solid and the dashed curves, i.e., between the required defensive potential and the defensive potential available from the own force build-up, that must be made up by outside forces. It should be pointed out, however, that the outside forces required in peace-time (t = 0) are identical to the values on the dotted curves at $t = T_{Rk} = 10$ when each of the three parties begins to respond to the build-up of the other two.

Table 6.1: Additional defensive combat power N_{Rk} (t) required for maintaining stability in peace time and during force build-up

k	t	N_{Dkmin} (t)	N_{Ak} (t)	N_{Rk} (t)	$a^*_{Rk}(t)$	N_{Rkadd} (t)
1	0	1,110	442	470	-	-
	10	1,727	442	1,086	-	-
	18.4	2,245	736	1,178	10.9	-
	50.2	2.776	1,105	1,174	0	-
2	0	1.100	552	334	-	-
	10	1.671	552	904	-	-
	18.9	2,181	1.380	856	0	-
	50.2	2,751	1.380	834	0	-
3	0	800	670	0	-	-
	10	1,444	670	487	-	-
	18.4	1.985	838	788	35.9	133
	18.9	2,000	849	787	0	-
	50.2	2.000	1.675	0	0	-

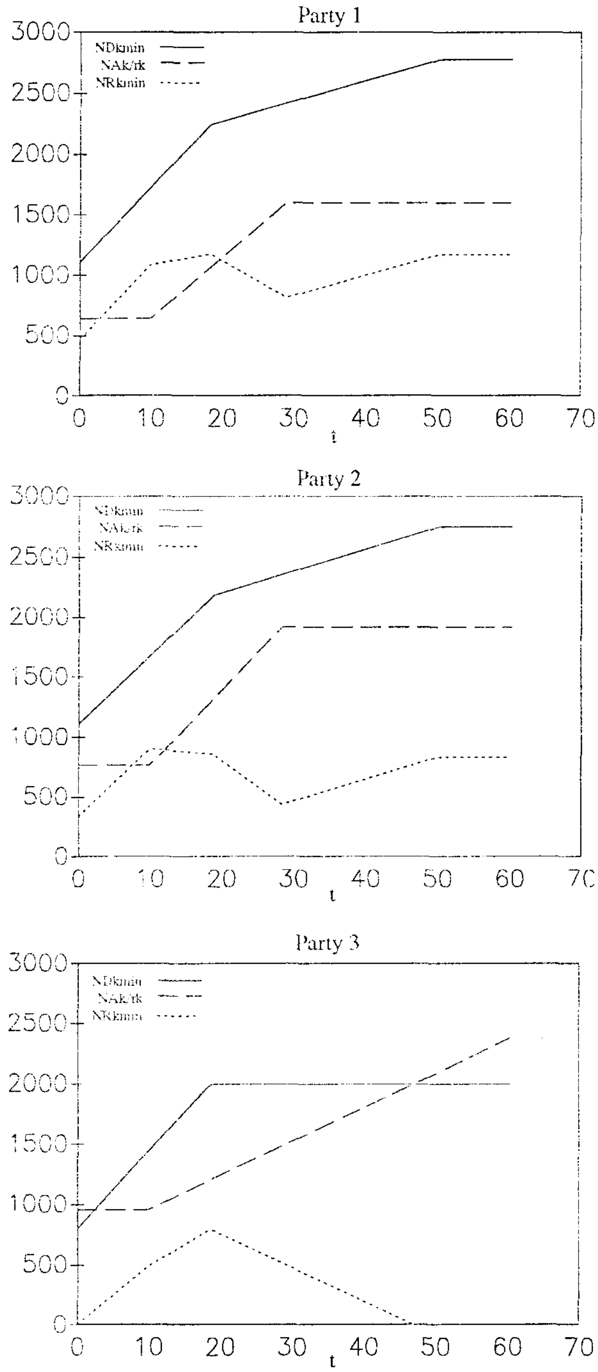

Figure 6.2: Build-up curves for regional parties and outside support

217. Thus, in order to provide stability between the three regional parties, third parties from outside the region must be prepared to deploy a defensive combat power of up to 1178 units to the respective region. Most of this outside defense potential (1086 units) must be available in peace time on short notice. This amounts to about 45 percent of the peace-time military potential in the respective region, and to about 20 percent of the regional military potential after full mobilization.

6.1.2.4 The Contribution of Air Power

218. The contribution of air power in estimating the combat power of a given force posture may be determined on the basis of either one of three models:

a. Model 1 assumes that scores can be provided in a consistent manner for the air and air defense weapon systems so that their combat power can simply be added to the combat power of the ground forces of a given party.

b. Model 2 decrements the combat power of air systems in some proportion to the opponent's air defense systems before adding the remaining air combat power and the combat power of the ground forces.

c. Model 3 decrements the combat power of the ground forces of a given party in some proportion to the opposing party's air power remaining after the latter has been decremented in some proportion to the former party's air defenses.

219. The three models reflect fundamentally different, but equally plausible, views on air-ground interactions. However, since there seems to be little empirical evidence to defining consistent scores, most assessments are apparently based on model 3. In contrast to models 1 and 2, model 3 does not require any scores for air and air defense systems. Rather, the reduction of air power due to air defenses, and the reduction of ground combat power due to the opponent's air power, can be calculated in a rather straightforward manner if some basic performance data of air and air defense weapons are known, and if reasonable operational assumptions can be made which reflect the mutual air war philosophies of the opponents and their likely air operational concepts in the types of conflicts considered in the assessment.

220. The approach used in the multipolar stability model ASAM corresponds to the third model and is based on three principal assumptions:

a. In a given instance, reasonable estimates can be provided on the number n_F of air systems surviving an eventual initial counter-air strike of the opponent.

b. In the initial (decisive) phase of a military conflict, both parties would employ substantial parts of their surviving air power (fraction f_F) in interdiction campaigns, the defending party in an attempt to reduce and delay the aggressor's ground forces prior to their assaults in main-thrust sectors, the aggressor in an attempt to deny the defender the timely build-up of counter-concentrations for repelling the aggressor's ground forces.

c. The performance of the air defenses available to both sides can be specified in terms of average sortie survival probabilities P_s to be expected in interdiction missions.

221. With these assumptions, the ground combat power N of the opponent that may be eliminated during the initial interdiction campaign lasting for T_F time units results as

$$N = n_F \; f_F c_F P_S \left(\frac{1-P_S^{S_F T_F}}{1-P_S} \right). \tag{6.18}$$

S_F denotes the sortie generation rate (sorties per time unit) of the ground support organization, c_F the average ground combat power of the opponent neutralized per surviving interdiction sortie. With the ground weapon system scores known, the c_F may be estimated from representative interdiction sortie performance data (e.g., expected number of ground force weapon systems of a given type killed per sortie) based on the assumption that the probability of a ground force weapon system being attacked by an interdiction sortie is equal to its relative presence in the inventory.

6.1.3 The Generalized Force Ratio Model GEFRAM

222. The analytical model GEFRAM is designed for estimating the stable regional force ratio (SRFR) in situations distinguished by reasonably well defined front lines. The SRFR represents the theater-wide ratio of the offensive combat power of the aggressor and the defensive combat power of the victim at which the stability criteria are met, i.e., $P \leq P^*$ for the sufficiency view, and $W \geq W^*$ for the security view (see chapter 6.1.1).

6.1.3.1 The Mathematical Model

223. The military objectives of an aggression are assumed to consist in more or less simultaneous breakthroughs being accomplished in a minimal number k out of $z \geq k$ main-

thrust sectors being uniformly distributed along the border or demarcation line between aggressor and victim. Therefore, the situation is regarded as stable if

$$\sum_{x=k}^{z} P(x, z) \leq P^* \qquad (6.19)$$

or

$$\sum_{x=0}^{k-1} P(x, z) \geq W^*, \qquad (6.20)$$

where P (x,z) is the binomial probability of x breakthroughs occurring when $z \geq x$ main-thrust sectors are implemented by the aggressor:

$$P(x, z) = \binom{z}{x} p^x (1-p)^{z-x} . \qquad (6.21)$$

p denotes the breakthrough probability in each of the z main-thrust sectors.

224. In a given scenario, the breakthrough probability is a function of the local attacker: defender combat power ratio k_l in a main-thrust sector. Thus, if the probability distribution function $p\,(k_l)$ is known, the local ratio k_l* which satisfies the stability condition (6.19) or (6.20) can be estimated.

225. As an illustrative example, Figure 6.3 shows breakthrough probability functions generated from the results of earlier simulation experiments with the model KOSMOS as well as the function that reportedly has been widely used in Soviet operations planning. Each of the dots and triangles was determined from 50 replications of battles involving assaults by Soviet motor rifle (MR) forces on a German armored infantry brigade defending from prepared positions in rolling hill-type terrain.

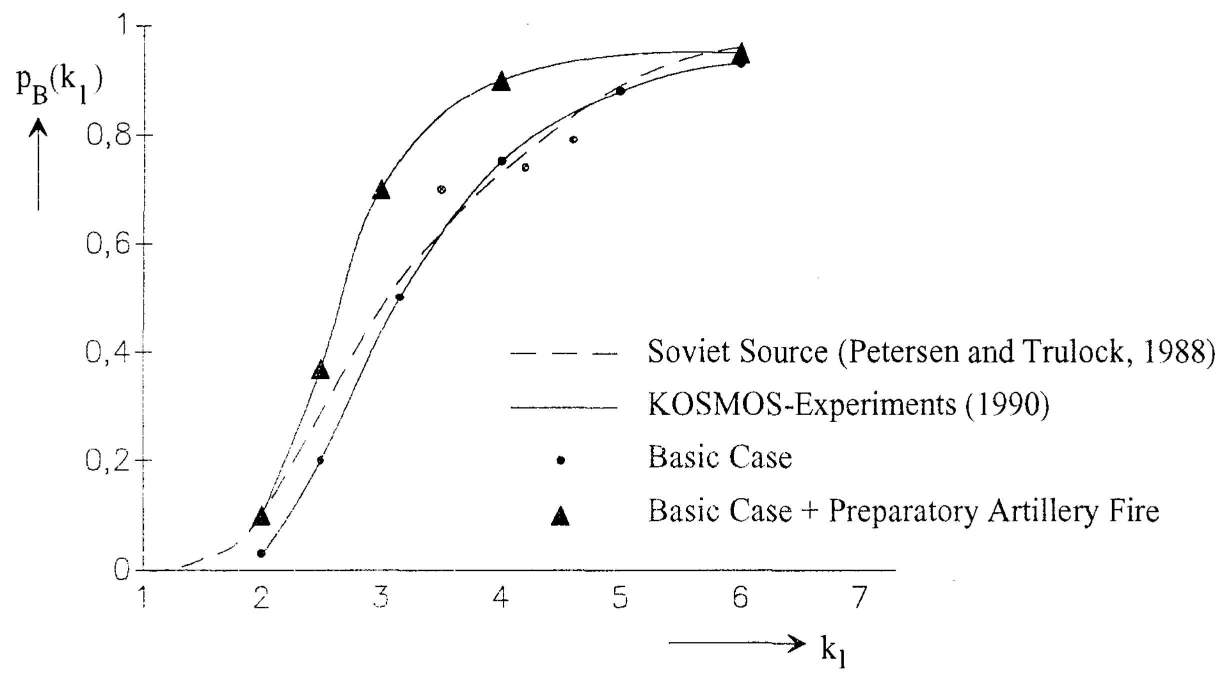

Figure 6.3: Probability of breakthrough $p_B(k_1)$ as a function of the local attacker: defender force ratio k_1 which denotes the weighted quotient of the initial number of tanks and APCs/IFVs on both sides: The KOSMOS experiments of 1990 simulated the assault of Soviet motor rifle forces against a well prepared German armored infantry brigade (PzGrenBrig) in rolling hill-type terrain, the preparatory fire was provided by the artillery support forces available to a Soviet MR division (900 tubes) and lasted for 45 minutes preceding the assault.

226. With k_1* known, the value F of the SRFR satisfying the stability criteria P* or W* results as

$$F = \begin{cases} \dfrac{k_1^*}{\left(1+\dfrac{\left(k_1^*(1-a)-k_2(1-g)\right)\left(1-r_A\right)}{k_{1F}^* a+k_2(1-g)}\right)} & \text{for } r_D > 0 \\[2ex] k_1^* a + k_2(1-g) & \text{for } r_D = 0 \end{cases} \qquad (6.22)$$

with

$$g = \frac{zw}{L}$$

$$a = \begin{cases} g\left(1 + \frac{2}{w}\sqrt{\left(\frac{v_D}{v_A}\right)^2 (d_T + d_P)^2 - d_P^2}\right) & \text{for} \begin{cases} d_P + d_T > 0 \\ \frac{v_D}{v_A} \geq \frac{d_P}{d_P + d_T} \\ k_2^* > k_2 \\ d_T < d_{TG} \end{cases} \\ 1 - \frac{k_2}{k_2^*}(1-g) & \text{for} \begin{cases} \frac{v_D}{v_A} \geq \frac{d_P}{d_P + d_T} \\ k_2^* > k_2 \\ d_T \geq d_{TG} \end{cases} \\ g & \text{otherwise} \end{cases} \tag{6.23}$$

$$d_{TG} = \begin{cases} \frac{v_A}{v_D}\sqrt{d_P^2 + \frac{1}{4}\left(\frac{L}{z} - w\right)^2 \left(1 - \frac{k_2}{k_2^*}\right)^2} - d_P & \text{for} \begin{cases} k_2^* > k_2 \\ v_D > 0 \end{cases} \\ 0 & \text{otherwise} \end{cases} \tag{6.24}$$

$$r_D = 1 - \frac{F\left(1 - r_A\right)}{k_1^* F a + k_2 (1-g)} \tag{6.25}$$

The variables in (6.22)-(6.25) denote:

L = width of theater of operations

z = number of main-thrust sectors

w = width of main-thrust sectors

v_A = average approach velocity of attacker elements

v_D = average redeployment velocity of defender elements

r_A = attacker's fraction in reserve ($0 \leq r_A \leq 1$)

r_D = defender's fraction in reserve ($0 \leq r_D \leq 1$)

d_p = penetration distance (from DL) at which defense wants to attain the combat power ratio k_1*

d_T = tactical warning distance (beyond DL) at which the size and direction of main-thrusts are identified by the defender

d_{TG} = tactical warning distance required for maximum possible redeployment of forward defense elements

k_1^* = combat power ratio in the main-thrust sectors required for deterring the attack

k_{1F}^* = combat power ratio in the main-thrust sectors required for holding action

k_2 = combat power ratio between the main-thrust sectors which the aggressor wants to maintain to guard against counter-attacks[1]

k_2^* = combat power ratio between the main thrust sectors which the defender wants to maintain to guard against infiltration.

227. Figure 6.4 shows a schematic representation of the operations modeled by (6.22) which assumes that the fraction ($1 - r_A$) of the total offensive combat power N_A available to the aggressor's ground forces is allocated to the initial attacks in z main-thrust sectors while simultaneously maintaining sufficient forces between the main-thrust sectors (ratio k_2) to hold against eventual counter-attacks by the forward deployed defender forces.

1 Since the defender's potential is measured in form of defensive combat power units, and the attacker's in terms of offensive combat power units, the specification of k_2 must account to the switch in roles, when the attacker is forced to defend against counter-attacks by the defender, by multiplying the "raw" quotient k_2 by a factor $\rho_A \rho_D$. The parameters ρ_A and ρ_D denote the quotients of the offensive and the defensive combat power available from the force posture of the attacker and defender respectively (see also Eq. (6.9).

228. The defender is assumed to have strategic warning about the imminent aggression, but no clues as to where to expect the initial attacks until they have come within the distance d_T beyond the demarcation line (DL). Thus, the defender decides to deploy a fraction ($1 - r_D$) of the total defensive combat power N_D of his ground forces more or less uniformly along the DL.The complementary fraction is held in reserve[2]

229. With the appropriate selection of independent variables, the model (6.22) can accommodate four basic operational concepts for the defense:

a. Initial forward deployment of sufficient forces for assuring k_I^* along the entire border of length L *(static forward defense)*;

b. Initial forward deployment of defense forces for assuring k_{IF}^* required for holding actions along the entire DL; subsequent deployment of operational reserves to the main-thrust sectors in order to bring about the counter-concentration required for deterrence (ratio $k_I^* < k_{IF}^*$) *(static defense with operational reserves)*;

c. Redeployment of forward forces in order to build up, in the main-thrust sectors, the counter-concentrations required for deterrence (ratio k_I^*) at a distance d_p from the demarcation line (DL), but leaving sufficient forces in between the main-thrusts (ratio k_2^*) to prevent an infiltration of aggressor forces *(mobile defense)*:

d. Redeployment of forward forces, in order to build up, in the main-thrust sectors, the combat power required for holding action (ratio k_{IF}^*) at a distance d_p from the demarcation line (DL), and deployment of operational reserves to the main-thrust sectors in order to bring about the counter-concentrations required for deterrence (ratio $k_I^* < k_{IF}^*$) *(mobile defense with operational reserves)*.

[2] Since the value F of the SRFR is equal to the inverse of the relative operational minimum, the fraction r_D of the victim's operational reserves is a dependent variable as shown by Eq. (6.25)

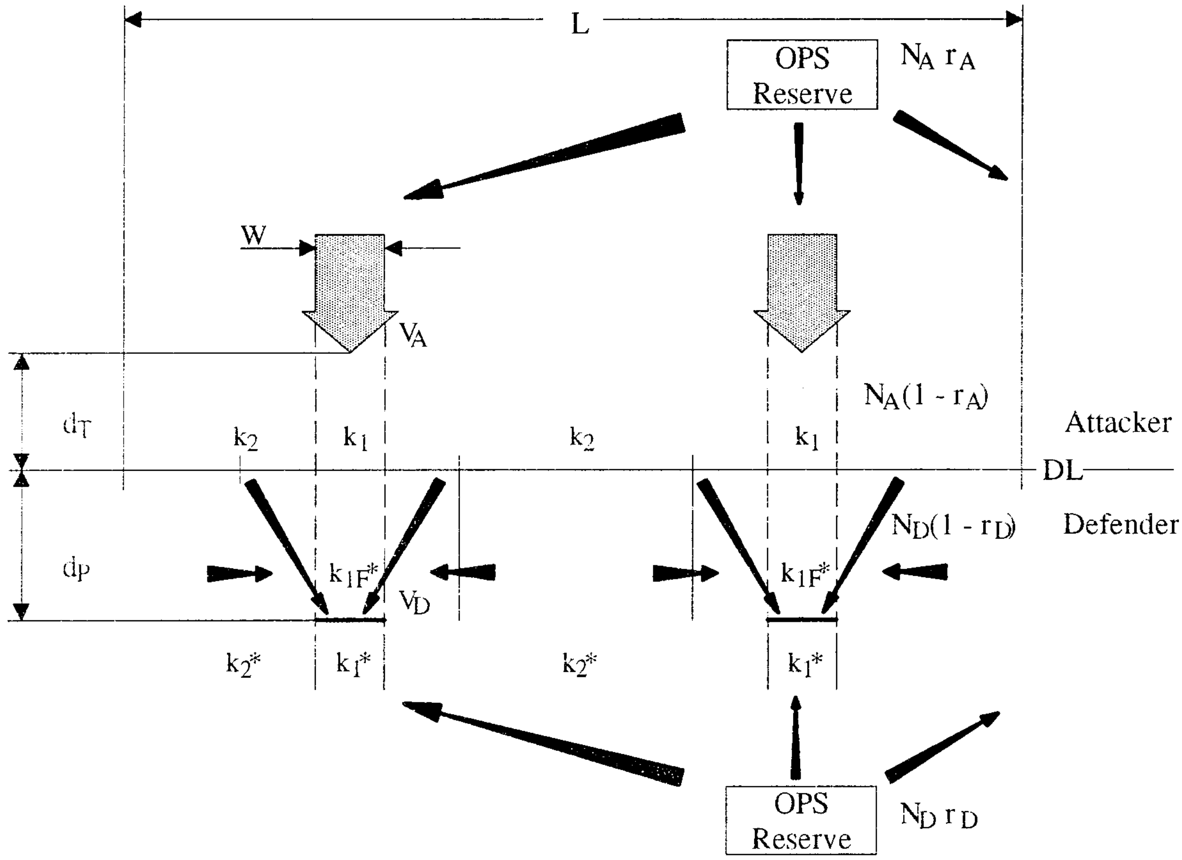

Figure 6.4 Basic Structure of the Generalized Force Ratio Model (GEFRAM)

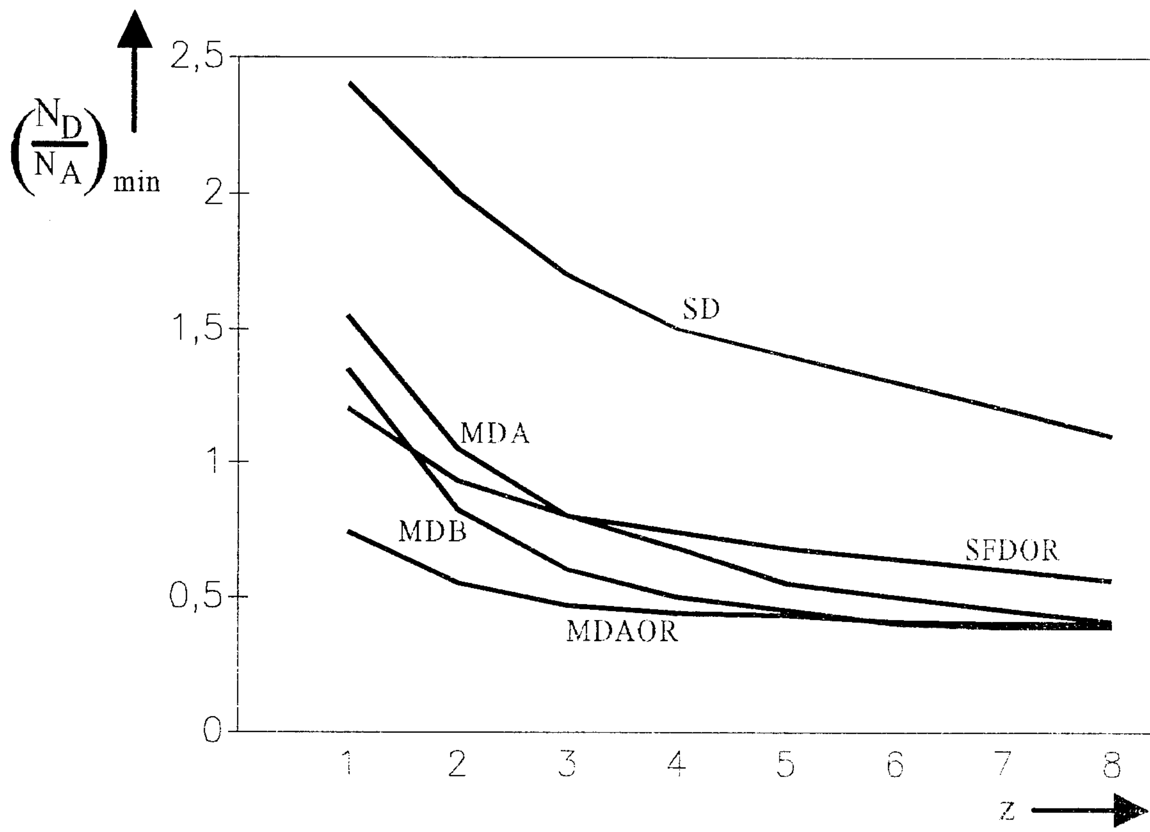

Figure 6.5: Relative operational minimum of the defense as a function of the number z of the aggressor's main-thrust sectors distributed evenly in a theater of width L = 800 km (w = 25 km, $k_1^* = 3 : 1$, $k_2 = 1 : 3$, $k_2^* = 3 : 1$, $r_A = 0.5$, $d_P = 0$ km, $d_T = 30$ km)

6.1.3.2 Sensitivity Analysis

230. In order to illustrate the sensitivity of the GEFRAM, the results of two sets of numerical experiments are presented. One addresses the question of the relative operational minimum for the four basic defense concepts mentioned above as a function of the number z of main-thrust sectors. The other looks at the impact of the stability criteria and the size of the theater on the SRFR.

231. The *relative operational minimum* of the defense is defined as the minimal defensive combat power N_D the victim needs to have for satisfying his stability criteria relative to the offensive combat power N_A available to the aggressor in the respective theater. Figure 6.5 shows the operational minima obtained from (6.22) for the indicated defense concepts as a function of the number z of main-thrust sectors, of width w = 25 km each, distributed evenly across a theater of width L = 800 km. It is assumed that the aggressor allocates 50 percent of his offensive combat power to the initial attack. 50 percent is held in reserve for feeding the main-thrust sectors. A local force ratio of $k_1^* = 3{:}1$ in each of the main-thrust sectors is assumed as sufficient for deterring the aggression, and of $k_{1F}^* = 6{:}1$ for performing delaying operations. In order to guard against counter-attacks and infiltrations between the main-thrust setors, a 3 : 1 superiority of the offensive party must not be exceeded, i.e.,$k_2 = 1{:}3$ and $k_2^* = 3{:}1$ if we assume, for the sake of simplification, that there is no difference between the offensive and defense combat power of the force postures for both parties ($\rho_A = \rho_D = 1$).

232. The general tendency of the results is quite plausible since the model does not place any constraints on the size of the forces that may be allocated to the main-thrust sectors: The higher the number of main-thrust sectors of the attacker, the fewer forces he can concentrate there and, consequently, the fewer defense forces are required for each defense concept to bring about the indicated force ratios of k_{1F}^* and k_1^* . Thus, it appears prudent to assume that the aggressor would implement the smallest number of main thrusts required for meeting his operational objectives. All curves asymptotically approach the ratio $(N_D : N_A)_{min} = 1 : 3$ which is reached when the attack is carried out in a true steam-roller fashion across the entire theater at z = L/w = 32.

233. It comes as no surprise that a stationary linear defense (SD) represents the most demanding defense concept when no operational reserves are available. As illustrated by the case SFDOR, operational reserves do reduce the operational minimum of a stationary linear defense considerably. However, the availability of operational reserves alone cannot match a mobile defense with the capability to redeploy the forward forces except when the latter's redeployment velocity is too low. In our example, this is the case when the mobile forward defense MDA is faced with an attack that is concentrated in not more than z = 3 main-thrust sectors, and MDB with an attack concentrated in one main-thrust sector. Within the time available for redeployment, i.e., the time it takes the attacking elements to cover the distance $d_T + d_p$, the

force ratio k_1^* required for deterrence is only obtained when the initial density of the forward deployed defense elements is sufficient to compensate for the smaller number of defense elements that may redeploy at lower velocity. In other words, as the mobility of defense elements increases, the required density of their forward deployment decreases the more the larger the number of the attacker's main-thrusts.

234. A comparison of the cases MDB and MDAOR suggests that, given a certain mobility, the availability of operational reserves is preferable to a further increase in the mobility of the forward forces. In a given theater, the mobility threshold at which the preference of forward force mobility over operational reserves is reversed depends primarily on the tactical warning distance d_T and the penetration distance d_p at which the attack is to be halted. It rises as d_p becomes smaller and falls when d_T increases.

235. For testing the sensitivity of the *stable regional force ratio* it is assumed that, irrespective of the length L of the militarily relevant border between them, all parties do pursue identical objectives and concepts for both, the defense of their territories and for eventual attacks on other parties.

236. With regard to the organization of attack and defense as well as the stability criteria, the following assumptions are made:

Attack: The attacking ground forces are divided into two echelons of equal size ($r_A = 0.5$). The attack is concentrated in two main-thrust sectors of 30 km each. In between the main-thrust sectors, the attacker maintains a covering force ratio of $k_2 = 1{:}3$ vis-à-vis the defender's front line forces. The attack is considered to be successful if a breakthrough is accomplished in at least one main-thrust sector.

Defense: The defender fights a delaying battle with forward deployed forces in the main-thrust sectors. Forward forces outside the main-thrust sectors are redeployed in order to build up holding action force ratios of $k_{1F}^* = 6{:}1$ in the main-thrust sectors. Simultaneously, operational reserves are brought forward to the main-thrust sectors where the stable local force ratio k_1^* is to be attained at a pene- tration distance of = 30 km. The redeployment velocity v_D of defense forces is assumed to be equal to the penetration velocity v_A of attacking forces. In between the main-thrust sectors, the defender maintains a covering force vis-à-vis the attacker's covering force at a force ratio of $k_2^* = 3{:}1$, or at k_1^* if $k_1^* < 3{:}1$. The tactical warning distance beyond the border, at which location and size of the main-thrusts are identified, is assumed as $d_T = 30$ km. Defense success requires that breakthroughs are averted in both main-thrust sectors.

Stability Criteria: In order to demonstrate the implications of the two basic types of stability criteria, the SRFR is determined for $P^* = 0.9$ and $W^* = 0.9$. The corresponding threshold values for the local breakthrough probability p in the mainthrust sectors are obtained from (6.19), (6.20), and (6.21) as $p = 0.684$ and $p = 0.051$, respectively. The stable local force ratio k_l^* is estimated from the Soviet probability distribution $p(k_l)$ shown in Figure 6.3 as $k_l^* = 3.67 : 1$ for $P^* = 0.9$ and $k_l^* = 1.67 : 1$ for $W^* = 0.9$.

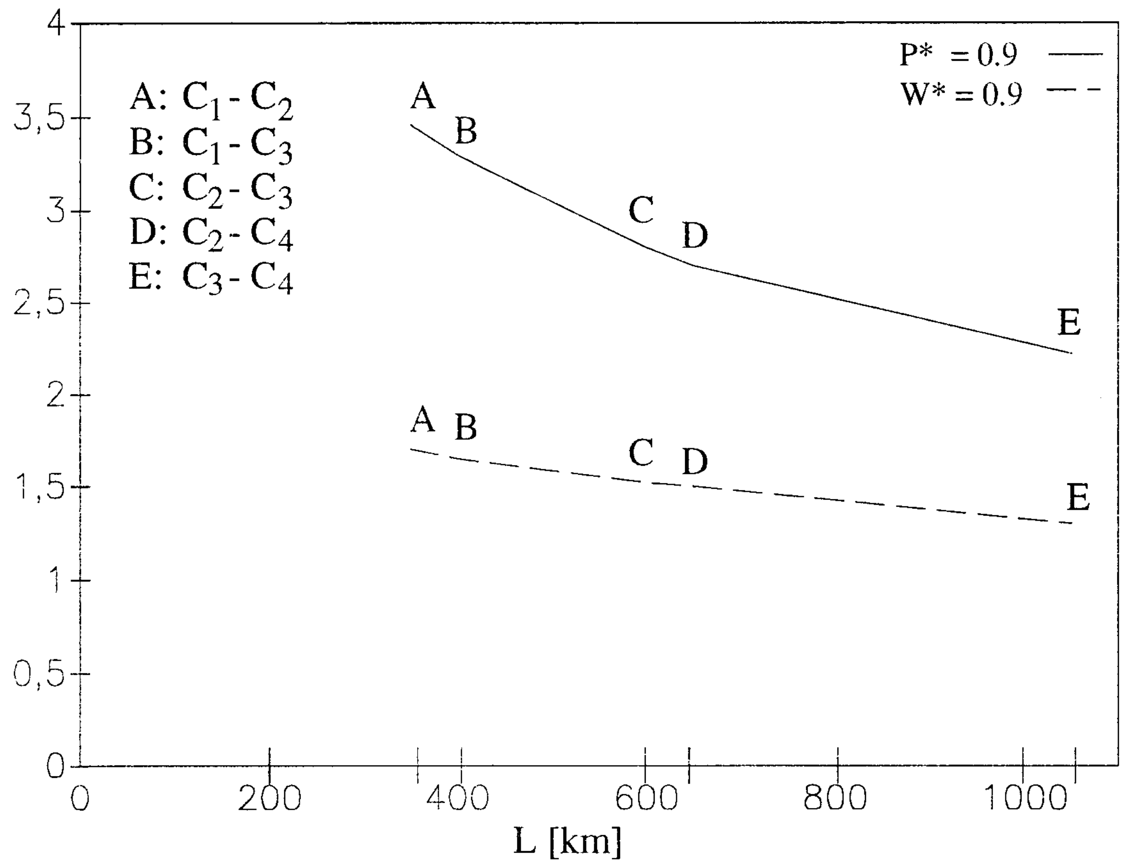

Figure 6.6: Stable Regional Force Ratio F as a function of the length L of the militarily relevant border between aggressor and victim

237. The values F of the SRFR resulting with these operational assumptions are shown in Figure 6.6 as a function of the length L of the border between parties. For the sake of illustration, the letters along the curves denote several pairs of fictitious opponents that will be referred to in the example presented in chapter 6.1.3.

238. The trends exposed by Figure 6.6 attest to the plausibility of GEFRAM: The longer the border a party has to defend, under otherwise identical circumstances, the lower the

SRFR it has to maintain, i.e., the more defense forces it has to provide for satisfying the stability criteria P* and W*. Of course, stability would also be obtainable with fewer defense forces if the party in question were willing to relax its operational defense requirements.

239. Take the case E of a confrontation between parties C 3 and C 4. The assumption that the defender wants to implement the counter-concentrations necessary for satisfying $P^* = 0.9$ at a distance of only $d_p = 30$ km from the border results in an SRFR of $F = 2.22$ for the defense of the 1050 km long border between the two parties. This requires them to maintain a defensive potential vis-à-vis a given offensive threat that is 56 % higher than what would be needed in case A for the defense of the 350 km long border between parties C 1 and C 2, for which the SRFR results as $F = 3.46$. The same SRFR would be sufficient in case E if both countries were to accept that the stability criterion $P^* = 0.9$ would be met at a distance of about $d_p = 500$ km from the border. For $d_p = 200$ km, a SRFR of $F = 2.58$ would be sufficient.

6.1.4 Example of a Multipolar Stability Analysis

240. Typical results that may be obtained from the SRFR-Model shali be illustrated by means of a simplified scenario involving four fictitious parties C1, C2, C3, and C4 in an arbitrary region. It is assumed that parties C1 and C4 are separated by the territories of parties C2 and C3, both of which have a common border with C1 and C4 each as well as between themselves.

6.1.4.1 Operational Assumptions and Combat Power

241. Since they have no common border between them, C1 and C4 threaten each other only in cooperation with C2 or C3, or both. In such situations, their forces are considered to reinforce those of C2 and C3 in proportion to the relative border length of C2 and C3 with the respective victim. Simultaneous threats by C2 and C3 involve a timely coordination of their attack operations that would , however, be executed independently.

242. The assumptions regarding the organization of attack and defense in eventual military conflicts between the four parties are identical to those stated in paragraph 55. Thus, the SRFR-values used in this example are obtained from Figure 6.6 as follows:

Oponents	L [km]	F (P*=0.9)	F (W*=0.9)
C1 - C2	350	3.46	1.65
C1 - C3	400	3.31	1.62
C2 - C3	600	2.84	1.51
C2 - C4	650	2.75	1.49
C3 - C4	1,050	2.22	1.33

243. The inventories of the four parties in the main weapon system categories of main battle tanks (MBT), towed and self-propelled artillery (ARTY), armored combat vehicles (ACV), combat aircraft and attack helicopters are summarized in Table 6.2. The indicated offensive and defensive combat power values are based on the asset scores and the situational multipliers, for mixed terrain and prepared defense, published by the RAND Corporation in 1992 (see Annex VI).

Table 6.2 Weapon System Inventories and Combat Power

Ground Forces

Country	Weapon System			Combat Power	
	MBT	ARTY	ACV	offensive	defensive
C1	1,730	1,610	2,150	4,614	5,330
C2	1,800	1,615	2,660	4,986	5,759
C3	4,080	4,040	5,050	11,098	12,821
C4	6,400	6,415	11,480	19,866	23,296

Air Forces

Country	Weapon System		Neutralized Ground Combat Power			
			P_s = 0.97		P_s = 0.80	
	Combat Aircraft	Attack Helicopters	offensive	defensive	offensive	defensive
C 1	460	130	1,647	1,902	883	1,021
C 2	260	80	956	1,104	511	590
C 3	1,090	330	4,042	4,670	2,161	2,496
C 4	3,450	890	11,531	13,313	6,216	7,177

244. The values of neutralized ground combat power associated with combat aircraft and attack helicopters are estimated by means of Eq. (6.18) based on the following assumptions:

a. Each surviving sortie kills one category item. Considering the average inventory mix of the ground forces of the four parties, this in equivalent to a combat power neutralized per air sortie of 0.84 when the air attack is directed at an attacking ground force, and of 0.97 when it is directed at a defending ground force.

b. Both the aggressor party and the defending party allocate 50 percent of their fixed wing combat aircraft and all of their attack helicopters to an air indiction campaign preceding the ground attack.

c. The interdiction campaign lasts for one day during which the sortie generation rate is 5 sorties for fixed wing aircraft and 8 sorties for helicopters.

d. The values assumed for the sortie survival probability P_s reflect standard (P_s = 0.97) and advanced (P_s = 0.8) air defense systems.

6.1.4.2 Results - Land Forces Only

245. For each party k, the results tables show, 1) the defensive combat power N_{Dk} available from its weapon holdings; 2) the minimal defensive combat power N_{Dkmin} required for satisfying the stability criterion when faced with aggression by the indicated attacker; and 3) the difference (N_{Dk} - N_{Dkmin}) between the available and the required defensive combat power. A positive value indicates a surplus in defense potential for party k, a negative value a deficit.

246. Tables 6.3 - 6.5 present the defensive combat power balances without air forces. The values in Table 6.3 suggest that, when the relations between the parties are non-controversial - as indicated by the military stability criterion of P* = 0.9 -, the assumed ground force inventory levels do provide all countries, except C2, a rather comfortable degree of stability as long as offensive coalitions are unlikely. For C2, a deficit in defensive combat power of -1,464, or 25 percent, exists vis-à-vis C4. Only the parties C3 and C4 can cope with all possible coalition threats.

247. However, if offensive coalitions cannot be dismissed from consideration, the results in Table 6.4 suggest that reductions of the inventory levels by 66 percent for C4 and by 44 percent for the C3 would eliminate instabilities of the system even when C1 or C2 are confronted with coalitions of the other three countries. The marginal deficits of -7 and -242

remaining for C2 and C3 in case of three-party threats are due to the reduction iterations being terminated when the largest remaining deficit is less than 5 percent of the total defensive combat power available to the respective party.[3]

248. Of course, the indicated reductions also turn the previous deficit of C2 vis-à-vis C4 into a sizeable surplus of 3,279. And the previous surplus of the C3 increases from 711 to 967 in case of the three-party threat because of the comparatively larger reductions of the C4 forces. Nevertheless, the C4 surplus of 1,325 vis-à-vis the other three countries still amounts to 17 percent of the defensive combat power of 7,873 available after a 66 percent reduction of its weapon holdings.

249. The results change rather dramatically if one assumes that the non-military relations between the parties were strained to the extent that all countries adopted the security-oriented view requiring a probability of defense success of at least 90 percent ($W^* = 0.9$). In that case the number of unstable situations increases by a factor of 2.2, from 6 in Table 6.3 to 13 in Table 6.5, including now all threats to C1 and C2 involving coalitions or the parties C3 and C4 by themselves. And even the comparatively strong C3 now shows a deficit of -2,073 combat power units vis-à-vis C4 alone as compared to as surplus of 3,858 for $P^* = 0.9$. Vis-à-vis the three-party threat from C1, C2, and C4 the defensive deficit of the C3 amounts to -8,220 for the security-oriented view $W^* = 0.9$ as opposed to a surplus of 711 for the sufficiency-oriented view $P^* = 0.9$. Only C4 has a significant surplus of defensive combat power in all cases.

250. Thus, there is no stability to speak of under the security paradigm $W = 0.9$ for the assumed weapon holdings. Table 6.6 shows that this is also true in case of three-party threats against each of the four countries, and in case of two-party threats against C1 and C2, when the reductions of 44 percent for the C3 and 66 percent for C4 are implemented that provide a stable situation for the sufficiency criterion $P^* = 0.9$. However, even with the more demanding security-oriented stability criterion $W^* = 0.9$, these reductions would leave all parties some surplus in defensive combat power if the formation of offensive coalitions could be dismissed from consideration.

6.1.4.3 The Impact of Air and Air Defense Forces

251. The results presented in Table 6.7 and 6.8 illustrate how the defensive combat power balance of the four countries must be expected to change when ground force attacks are presumed to be preceded by air interdiction campaigns waged by the aggressor and, in response, by the victim as well. These changes are quite dramatic, especially since the data

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[3] The reductions are determined iteratively, starting and proceeding, in each iteration step, with the party that has the largest surplus in defensive combat power.

pertain to the sufficiency-oriented stability view at $P^* = 0.9$, and since the assumptions with regard to the effectiveness of air sorties appear to be rather conservative. In most cases we observe a reduction of whatever surplus in defensive combat power the parties may have had before, and an increase in their deficits.

252. Given standard air defense conditions ($P_s = 0.97$), the number of cases that show a deficit in defensive combat power increases by a factor of 2.2 (from 6 in Table 6.3 to 13 in Table 6.7) when the assumed aircraft and helicopter holdings are accounted for. Every previous surplus in defensive ground force combat power turns into a deficit when parties are faced with superior air power, such as C1 and C2 vis-à-vis C3 and C4, or C3 vis-à-vis C4.

253. The results in Table 6.8 suggest that the availability of advanced air defense systems (which are assumed to reduce the sortie survival probability from 0.97 to 0.8) would mitigate the destabilizing effects of air power. However, the (large) number of instable cases (13) remains the same. The cases of C1, C2, and C3 involving attacks by C4 show that there may be a limit to compensating for superiority in air power by increasing air defense performance.

254. Considering the trend revealed by the results of the cases involving ground forces only, the observed destabilizing effects of offensive air power must be expected to be significantly reinforced in case the parties preferred the security-oriented view on stability over the sufficiency-oriented one.

6.1.4.4 Concluding Observations

255. The result of our fictitious example suggest that, within certain limits, reductions in weapon holdings would contribute significantly to improving regional stability by reducing deficits in defensive combat power. This is especially true for reductions in the air combat power available to party C4 and, to a lesser degree, party C3.

256. Short of the availability of NOD-type systems, there is little room for unilateral improvements of stability in our example since the SRFR-values imply rather favourable circumstances for the defending parties such as no strategic and tactical surprise, and that the operational reserves of the defending parties are activated and deployed in a manner that assures their arrival at the desired points of counter-concentration prior to the time when the aggressor forces arrive there. Thus, in addition to timely early warning and responsive political and military decision processes, the defense forces are assumed to have a high degree of mobility, real-time command and control, and the means for delaying the aggressor forces.

257. However, the four parties would come a long way to reducing their defensive combat power deficits if they never were to join an offensive coalition and would always come to the help of whichever party was threatened by aggression. For example, even for the

security-oriented stability criterion would a defensive coalition of the parties C1, C2, and C3 have a surplus in defensive combat power of nearly 2,000 units vis-à-vis a combined air-land threat by party C4 under standard air defense conditions. A surplus of about 1,000 defensive combat power units would result if C1 and C2 were to form a coalition whenever one of them is threatened by C3.

258. If the formation of defensive alliances in the region is unlikely, and unilateral improvements of the defense capabilities of the parties not to be expected, maintaining stability would thus require that external forces are provided by third parties, or by the international community, capable of filling the defensive combat power deficits that exist between the regional parties. In order to keep the costs for maintaining regional stability as low as possible, the international community may well demand that the regional parties reduce their forces in a manner that minimizes regional deficits.

Table 6.3: Defensive Combat Power Balance for P* = 0.9 - without air forces

Defender k	Attacker i	C2	C3	C2 + C3	C2 + C4	C3 + C4	C2 + C3 + C4
C1	N_{Dk}	5,330	5,330	5,330	5,330	5,330	5,330
	N_{Dkmin}	1,440	3,350	4,791	7,179	9,348	10,668
	N_{Dk} -N_{DKmin}	3,890	1,980	539	-1,849	-4,019	-5,338

Defender k	Attacker i	C1	C3	C4	C1 + C3	C1 + C4	C1 + C3 + C4
C2	N_{Dk}	5,759	5,759	5,759	5,759	5,759	5,759
	N_{Dkmin}	1,333	3,903	7,222	5,236	8,555	12,458
	N_{Dk} -N_{DKmin}	4,426	1,856	-1,464	523	-2,797	-6,699

Defender k	Attacker i	C1	C2	C4	C1 + C2	C1 + C4	C1 + C2 + C4
C3	N_{Dk}	12,821	12,821	12,821	12,821	12,821	12,821
	N_{Dkmin}	1,393	1,754	8,963	3,146	10,356	12,109
	N_{Dk} -N_{DKmin}	11,428	11,067	3,858	9,674	2,465	711

Defender k	Attacker i	C2	C3	C2 + C3	C1 + C2	C1 + C3	C1 + C2 + C3
C4	N_{Dk}	23,296	23,296	23,296	23,296	23,296	23,296
	N_{Dkmin}	1,813	5,007	6,820	3,490	7,088	8,746
	N_{Dk} -N_{DKmin}	21,123	17,929	16,117	19,446	15,848	14,190

Table 6.4: Defensive Combat Power Balance for P* = 0.9 when weapon holdings are reduced 66 % by C 4 and 44 % by C 3 - without air forces

Defender k	Attacker i	C2	C3	C2 + C3	C2 + C4	C3 + C4	C2 + C3 + C4
C1	N_{Dk}	5,330	5,330	5,330	5,330	5,330	5,330
	N_{Dkmin}	1,440	1,879	3,319	3,410	3,938	5,337
	N_{Dk} -N_{DKmin}	3,889	3,450	2,010	1,919	1,392	-7

Defender k	Attacker i	C1	C3	C4	C1 + C3	C1 + C4	C1 + C3 + C4
C2	N_{Dk}	5,759	5,759	5,759	5,759	5,759	5,759
	N_{Dkmin}	1,333	2,189	2,479	3,522	3,812	6,001
	N_{Dk} -N_{DKmin}	4,426	3,570	3,279	2,237	1,946	-242

Defender k	Attacker i	C1	C2	C4	C1 + C2	C1 + C4	C1 + C2 + C4
C3	N_{Dk}	7,190	7,190	7,190	7,190	7,190	7,190
	N_{Dkmin}	1,390	1,754	3,077	3,146	4,469	6,223
	N_{Dk} -N_{DKmin}	5,797	5,437	4,114	4,044	2,721	967

Defender k	Attacker i	C1	C2	C4	C1 + C2	C1 + C4	C1 + C2 + C4
C4	N_{Dk}	7,873	7,873	7,873	7,873	7,873	7,873
	N_{Dkmin}	1,813	1,754	3,077	3,146	4,469	6,223
	N_{Dk} -N_{DKmin}	6,060	5,065	3,252	4,383	2,984	1,325

Table 6.5: Defensive Combat Power Balance for W* = 0.9 - without air forces

Defender k	Attacker i	C2	C3	C2 + C3	C2 +C4	C3 +C4	C2 + C3 + C4
C1	N_{Dk}	5,330	5,330	5,330	5,330	5,330	5,330
	N_{Dkmin}	3,021	6,853	9,874	15,059	19,119	22,034
	N_{Dk} -N_{DKmin}	2,308	-1,523	-4,544	-9,729	-13,790	-16,704

Defender k	Attacker i	C1	C3	C4	C1 + C3	C1 + C4	C1 + C3 + C4
C2	N_{Dk}	5,759	5,759	5,759	5,759	5,759	5,759
	N_{Dkmin}	2,795	7,342	13,352	10,137	16,147	23,489
	N_{Dk} -N_{DKmin}	2,963	-1,583	-7,593	-4,379	-10,389	-17,730

Defender k	Attacker i	C1	C2	C4	C1 + C2	C1 + C4	C1 + C2 + C4
C3	N_{Dk}	12,821	12,821	12,821	12,821	12,821	12,821
	N_{Dkmin}	2,849	3,299	14,893	6,148	17,742	21,041
	N_{Dk} -N_{DKmin}	9,972	9,522	-2,073	6,673	-4,921	-8,220

Defender k	Attacker i	C2	C3	C2 + C3	C1 + C2	C1 + C3	C1 + C2 + C3
C4	N_{Dk}	23,296	23,296	23,296	23,296	23,296	23,296
	N_{Dkmin}	3,321	8,320	11,671	6,452	11,778	14,993
	N_{Dk} -N_{DKmin}	19,975	14,976	11,625	16,844	11,518	8,303

Table 6.6: Defensive Combat Power Balance for W* = 0.9 when weapon holdings are reduced 66 % by C 4 and 44 % by C 3 - without air forces

Defender k	Attacker i	C2	C3	C2 + C3	C2 + C4	C3 C	C2 + C3 + C 4
C1	N_{Dk}	5,330	5,330	5,330	5,330	5,330	5,330
	N_{Dkmin}	3,021	3,843	6,864	7,153	8,054	11,038
	N_{Dk} -N_{DKmin}	2,308	1,486	-1,535	-1,824	-2,724	-5,709

Defender k	Attacker i	C1	C3	C4	C1 + C3	C1 + C4	C1 + C3 + C4
C2	N_{Dk}	5,759	5,759	5,759	5,759	5,759	5,759
	N_{Dkmin}	2,795	4,118	4,583	6,913	7,379	11,496
	N_{Dk} -N_{DKmin}	2,963	1,641	1,175	-1,155	-1,620	-5,738

Defender k	Attacker i	C1	C2	C4	C1 + C2	C1 + C4	C1 + C2 + C4
C3	N_{Dk}	7,190	7,190	7,190	7,190	7,190	7,190
	N_{Dkmin}	2,849	3,299	5,112	6,148	7,961	11,260
	N_{Dk} -N_{DKmin}	4,341	3,891	2,078	1,034	-771	-4,070

Defender k	Attacker i	C 2	C 3	C2 + C3	C1 + C2	C1 + C3	C1 + C2 + C3
C 4	N_{Dk}	7,873	7,873	7,873	7,873	7,873	7,873
	N_{Dkmin}	3,351	4,666	8,017	6,452	8,125	11,339
	N_{Dk} -N_{DKmin}	4,522	3,207	-144	1,421	-251	-3,466

Table 6.7: Defensive Combat Power Balance for P* = 0.9 - with air forces and standard air defense systems (P_s = 0.97)

Defender k	Attacker i	C2	C3	C2 + C3	C2 + C4	C3 + C4	C2 + C3 + C4
C1	N_{Dk}	4,226	660	444	-9,088	-12,653	-13,757
	N_{Dkmin}	965	2,853	4,294	6,703	8,851	10,170
	N_{Dk} -N_{DKmin}	3,261	-2,193	-4,738	-15,791	-21,505	-23,928

Defender k	Attacker i	C1	C3	C4	C1 + C3	C1 + C4	C1+ C3 + C4
C2	N_{Dk}	3,856	1,089	-7,555	-813	-9,457	-14,127
	N_{Dkmin}	1,057	3,567	6,875	4,899	8,208	12,110
	N_{Dk} -N_{DKmin}	2,800	-2,478	-14,430	- 5713	-17,665	-26,237

Defender k	Attacker i	C1	C2	C4	C1 + C2	C1 + C4	C1 + C2 + C4
C3	N_{Dk}	10,918	11,717	493	9,814	-2,395	-3,499
	N_{Dkmin}	173	332	7,139	1,725	8,532	10,286
	N_{Dk} -N_{DKmin}	10,745	11,384	-7,632	8,089	-10,927	-13,785

Defender k	Attacker i	C2	C3	C2 + C3	C1 + C2	C1 + C3	C1 + C2 + C3
C4	N_{Dk}	21,832	18,267	17,163	19,930	16,364	15,260
	N_{Dkmin}	-2,380	-196	1,617	-702	1,886	3,544
	N_{Dk} -N_{DKmin}	24,212	18,462	15,546	20,632	14,479	11,716

Table 6.8 Defensive Combat Power Balance for P* = 0.9 - with air forces and advanced air defense systems (P_s = 0.80)

Defender k	Attacker i	C2	C3	C2 + C3	C2 + C4	C3 + C4	C2 + C3 + C4
C1	N_{Dk}	4,740	2,833	2,244	-2,437	-4,343	-4,933
	N_{Dkmin}	1,185	3,084	4,524	6,924	9,081	10,401
	N_{Dk} -N_{DKmin}	3,555	-250	-2,280	-9,360	-13,425	-15,344

Defender k	Attacker i	C1	C3	C4	C1 + C3	C1 + C4	C1 + C3 + C4
C2	N_{Dk}	4,738	3,262	-1,418	2,242	-2,439	-4,935
	N_{Dkmin}	1,185	3,723	7,037	5,056	8,369	12,272
	N_{Dk} -N_{DKmin}	3,553	-461	-8,455	-2,814	-10,808	-17,207

Defender k	Attacker i	C1	C2	C4	C1 + C2	C1 + C4	C1 + C2 + C4
C3	N_{Dk}	11,800	12,231	5,644	11,210	4,623	4,034
	N_{Dkmin}	741	994	7,988	2,387	9,381	11,134
	N_{Dk} -N_{DKmin}	11,059	11,237	-2.34	8,824	-4.76	-7,101

Defender k	Attacker i	C2	C3	C2 + C3	C1 + C2	C1 + C3	C1 + C2 + C3
C4	N_{Dk}	22,346	20,440	19,850	21,326	19,419	18,830
	N_{Dkmin}	- 447	2,202	4,015	1,203	4,284	5,942
	N_{Dk} -N_{DKmin}	22,793	18,238	15,835	20,096	15,136	12,888

6.2 TESTING FUNDAMENTAL ASSUMPTIONS

259. The viability of the SRFR-concept depends on whether or not its two fundamental assumptions can be validated. One relates to the availability of adequate *scoring systems* for measuring, in form of a scalar value, the offensive and defensive combat power of heterogenous force postures. The other holds that distribution functions can be generated for the probability that an aggressor breaks through the victim's defenses as a function of the local aggressor: victim combat power ratio in main-thrust sectors.

260. It goes without saying that a comprehensive effort for the validation of both assumptions was beyond the means available to the RSG.18. However, the KOSMOS combat simulation experiments designed for testing stability hypotheses did provide a data base sufficient for validations in case of confrontations between armored and mechanized forces, thus demonstrating the principal feasibility of validation studies based on combat simulation.

261. A detailed description of the KOSMOS simulation model, the simulation scenarios, and the results of the simulation experiments, including the specification of breakthrough probability distributions, is contained in Annex IV 3. This chapter is confined to the evaluation of experiments for the purpose of validating scoring systems.

6.2.1 On Scoring Systems

262. Almost all scoring systems presently being used in the Western world are some variants of the American WEI-WUV-method. They use so-called asset scores as a measure for the basic combat power of the individual assets (weapon systems or military units) in a force. To varying degrees, situational multipliers are provided which permit accounting for different situational circumstances such as force mission (attack, defense), type of battle (break-through, withdrawal, delay, defense), defense preparation (fortified, prepared, deliberate, hasty), terrain (open, mixed, rough, urban, mountain) etc. For given situational circumstances, the total combat power of a military force results as the sum of the combat power provided by all assets in the force.

263. It has been argued the empirical basis for the WEI-WUV scores is ill-defined and highly questionable especially with a view to circumstances other than those prevailing in attrition warfare at high force levels. Therefor, various authors have postulated that systematic research be undertaken which combines historical analyses, combat simulation experiments, and military judgment for generating a relevant data base for the validation and adaption of existing scoring systems. Besides, it would be highly desirable that combat simulation

experiments organized for whatever purpose be routinely evaluated by means of appropriate mathematical techniques for the purpose of estimating weapon system or unit scores.

6.2.2. The Validation Experiments

264. The results of 2400 experiments have been evaluated by means of the antipotential-potential (APP)-method for the purpose generating scores. The initial attacker:defender combat power ratios (CPR) resulting with these scores are then compared to those obtained from existing scoring systems.

265. The scenarios of the validation experiments feature engagements between an attacking generic tank division, consisting of three brigades, and one defending mechanized infantry brigade of type I under two different conditions each for the visibility (good, poor), the terrain (mixed, open), and the degree of defense preparation (prepared, deliberate). The variation in the initial CPR was accomplished by reducing the initial strength of the attacking division or of the defending brigade in an appropriate manner. The thus resulting 48 scenarios are shown in Table 6.9. In the subsequent paragraphs, each scenario is identified by a six digit code. For example MGD 2.0 denotes the following scenario: mixed terrain (M), good visibility (G), deliberate defense (D), initial attacker strength = 70 %, initial defender strength = 100 %.

266. The structure and the TOE (table of equipment) of the generic tank division and the generic mechanized infantry brigade are defined at Annex IV 3. The equipment comprises the following assets:

MMBT	main battle tank (Leopard 2)
AFV	armored fighting vehicle (Marder 2)
ATRS	anti-tank rocket system (TOW 2-Jaguar)
MIT	mobile infantry team (TOW 2)
SRAD	short range air defense system (Roland/Gepard)
AHOW	self-propelled howitzer (M 109)
RL	rocket launcher (BM-21)
ATHEL	anti-tank helicopter (OH-58 D)
CHEL	combat helicopter (Hind E).

Table 6.9 a Combat simulation scenarios for testing scoring systems

Attacker: Tank Division
Defender: Mechanized Infantry Brigade Typ I

Scenario	Initial Strength (IS)		Terrain	Visibility	Defense Preparation	IS-Code
	Attacker	Defender				
1	70 %	100 %	O	G	D	2.0
2	70 %	100 %	M	G	D	
3	70 %	100 %	O	P	D	
4	70 %	100 %	M	P	D	
5	70 %	100 %	O	G	P	
6	70 %	100 %	M	G	P	
7	70 %	100 %	O	P	P	
8	70 %	100 %	M	P	P	
9	85 %	100 %	O	G	D	2.5
10	85 %	100 %	M	G	D	
11	85 %	100 %	O	P	D	
12	85 %	100 %	M	P	D	
13	85 %	100 %	O	G	P	
14	85 %	100 %	M	G	P	
15	85 %	100 %	O	P	P	
16	85 %	100 %	M	P	P	
17	100 %	100 %	O	G	D	3.0
18	100 %	100 %	M	G	D	
19	100 %	100 %	O	P	D	
20	100 %	100 %	M	P	D	
21	100 %	100 %	O	G	P	
22	100 %	100 %	M	G	P	
23	100 %	100 %	O	P	P	
24	100 %	100 %	M	P	P	

O: open **G**: good **P**: prepared
M: mixed **P**: poor **D**: deliberate

Table 6.9 b Combat simulation scenarios for testing scoring systems (cont'd)

Attacker: Tank Division
Defender: Mechanized Infantry Brigade Typ I

Scenario	Initial Strength (IS)		Terrain	Visibility	Defense Preparation	IS-Code
	Attacker	Defender				
25	100 %	85 %	O	G	D	3.5
26	100 %	85 %	M	G	D	
27	100 %	85 %	O	P	D	
28	100 %	85 %	M	P	D	
29	100 %	85 %	O	G	P	
30	100 %	85 %	M	G	P	
31	100 %	85 %	O	P	P	
32	100 %	85 %	M	P	P	
33	100 %	75 %	O	G	D	4.0
34	100 %	75 %	M	G	D	
35	100 %	75 %	O	P	D	
36	100 %	75 %	M	P	D	
37	100 %	75 %	O	G	P	
38	100 %	75 %	M	G	P	
39	100 %	75 %	O	P	P	
40	100 %	75 %	M	P	P	
41	100 %	65 %	O	G	D	4.5
42	100 %	65 %	M	G	D	
43	100 %	65 %	O	P	D	
44	100 %	65 %	M	P	D	
45	100 %	65 %	O	G	P	
46	100 %	65 %	M	G	P	
47	100 %	65 %	O	P	P	
48	100 %	65 %	M	P	P	

O: open **G**: good **P**: prepared
M: mixed **P**: poor **D**: deliberate

267. The average weapon system weights computed with the APP-method[4] are listed in Tables 6.10 and 6.11. In the terminology of scoring systems, each of these weights represents the product of the respective asset score and the situational multipliers.

268. When considering the values in Tables 6.10 and 6.11 it must be kept in mind that they reflect the particular circumstances and events of the respective simulated engagements and the underlying tactical rules. For example, the correlation between asset weights and the initial ratio of attacker:defender strength that can be observed for some assets, such as MMBT, AHOW and RL, reflects the rules for employing operational reserves and fire support assets in order to prevent local break-throughs in the defender's case, and to reinforce an imminent break-through in the attacker's case. Thus, the likelihood of their employment and, as a consequence, their weight increases for both sides as the initial strength of the attacker increases relative to the strength of the defender.

269. However, weights obtained from the KOSMOS experiments cannot be compared directly with the weights resulting from scoring systems anyway. This is because, in general, the latter are defined at higher levels of aggregation considering, if at all, tactics implicitely. Besides, for their use in the ASAM, it is more interesting to know whether the results of simulation experiments do validate, or rather falsify, scoring systems with regard to the CPR obtained from both of them.

270. To this end, Table 6.12 lists the CPR values obtained from the four different scoring approaches considered in this study in comparison to those resulting when the asset weights in Table 6.10 and 6.11 are used. Each of the four scoring approaches is based on the asset scores of the British *Balance Analysis Modelling System* (BAMS) applying either the general asset weight for both attacker and defender (BAM-G), or the asset weights for attack and defense (BAM-A/D), or the situational multipliers used in RAND's *Situational Force Scoring* (BAM-G-SM).[5] Except for BAM-G-generic, all approaches use the scores for the weapon systems employed in the simulation experiments as listed in paragraph 266 . BAM-G-generic considers generic assets the scores of which are assumed to be identical to the general weight of the respective asset class of BAMS.

271. For the ease of comparison, the CPR values presented in Table 6.12 are plotted in Figure 6.7 over the initial attacker:defender strength ratio measured in terms of BAM-G-Kosmos for each of the eight combinations of terrain-visibility-defense preparation underlying the simulation scenarios. The thick line represents the CPRs resulting from the KOSMOS experiments, the thin lines those resulting with the four scoring approaches.

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4 A detailed description of the APP-method is presented in Annex V. It should be noted, however, that contrary to the traditional application of this method, it is assumed that the initial value of an asset is not represented by the average number of victims killed per asset, but rather by the square root of this number.

5 BAMS does not provide situational multipliers. The multipliers of RAND's situational force scoring system do not distinguish between different visibility conditions.

Table 6.10 a Average attacker weapon weights

Sz	MMBT	AFV	ATRS	MIT	SRAD	AHOW	RL	CHEL
MGD2.0	0.138	0.048	0.292	0.062	0.175	0.140	0.214	0.000
MGD2.5	0.185	0.080	0.373	0.086	0.215	0.157	0.208	0.001
MGD3.0	0.234	0.113	0.466	0.100	0.254	0.185	0.239	0.013
MGD3.5	0.283	0.121	0.535	0.119	0.239	0.187	0.301	0.082
MGD4.0	0.335	0.145	0.591	0.118	0.218	0.190	0.350	0.171
MGD4.5	0.380	0.159	0.662	0.106	0.212	0.183	0.360	0.123
MGP2.0	0.089	0.030	0.207	0.039	0.111	0.159	0.251	0.000
MGP2.5	0.136	0.051	0.279	0.049	0.164	0.169	0.282	0.000
MGP3.0	0.179	0.063	0.344	0.073	0.172	0.208	0.285	0.018
MGP3.5	0.217	0.077	0.407	0.086	0.241	0.181	0.265	0.020
MGP4.0	0.260	0.110	0.514	0.101	0.252	0.141	0.285	0.018
MGP4.5	0.322	0.116	0.603	0.120	0.252	0.125	0.346	0.081
OGD2.0	0.177	0.050	0.338	0.022	0.278	0.097	0.151	0.002
OGD2.5	0.236	0.089	0.430	0.036	0.302	0.120	0.214	0.068
OGD3.0	0.285	0.099	0.506	0.038	0.259	0.168	0.305	0.195
OGD3.5	0.331	0.119	0.535	0.045	0.287	0.176	0.280	0.252
OGD4.0	0.343	0.136	0.563	0.047	0.302	0.187	0.258	0.196
OGD4.5	0.345	0.141	0.562	0.046	0.248	0.178	0.254	0.186
OGP2.0	0.131	0.030	0.261	0.014	0.216	0.101	0.205	0.000
OGP2.5	0.161	0.048	0.332	0.021	0.294	0.118	0.224	0.033
OGP3.0	0.227	0.072	0.430	0.025	0.303	0.113	0.198	0.096
OGP3.5	0.277	0.084	0.513	0.036	0.333	0.112	0.259	0.131
OGP4.0	0.316	0.102	0.588	0.039	0.305	0.112	0.247	0.191
OGP4.5	0.362	0.131	0.642	0.048	0.275	0.103	0.256	0.206

Table 6.10 b Average attacker weapon weights (cont'd)

Sz	MMBT	AFV	ATRS	MIT	SRAD	AHOW	RL	CHEL
MPD2.0	0.157	0.084	0.077	0.160	0.054	0.197	0.269	0.000
MPD2.5	0.191	0.087	0.092	0.204	0.067	0.225	0.298	0.001
MPD3.0	0.229	0.109	0.113	0.213	0.076	0.269	0.332	0.004
MPD3.5	0.259	0.107	0.094	0.240	0.043	0.301	0.412	0.001
MPD4.0	0.296	0.120	0.123	0.280	0.017	0.337	0.431	0.000
MPD4.5	0.353	0.137	0.124	0.301	0.000	0.333	0.468	0.000
MPP2.0	0.120	0.076	0.061	0.132	0.042	0.165	0.332	0.000
MPP2.5	0.153	0.077	0.066	0.170	0.045	0.169	0.322	0.000
MPP3.0	0.181	0.098	0.075	0.193	0.055	0.195	0.364	0.000
MPP3.5	0.200	0.102	0.081	0.208	0.044	0.223	0.370	0.001
MPP4.0	0.224	0.105	0.091	0.242	0.015	0.206	0.440	0.001
MPP4.5	0.263	0.123	0.098	0.278	0.001	0.217	0.465	0.001
OPD2.0	0.156	0.080	0.083	0.169	0.049	0.221	0.227	0.000
OPD2.5	0.194	0.097	0.103	0.208	0.051	0.249	0.269	0.002
OPD3.0	0.220	0.105	0.106	0.220	0.058	0.339	0.389	0.006
OPD3.5	0.248	0.108	0.106	0.237	0.046	0.349	0.381	0.000
OPD4.0	0.295	0.130	0.146	0.285	0.014	0.368	0.367	0.000
OPD4.5	0.327	0.142	0.122	0.301	0.000	0.364	0.340	0.000
OPP2.0	0.112	0.065	0.054	0.125	0.034	0.197	0.312	0.000
OPP2.5	0.148	0.090	0.074	0.165	0.048	0.189	0.297	0.000
OPP3.0	0.170	0.094	0.074	0.190	0.047	0.257	0.335	0.000
OPP3.5	0.196	0.107	0.102	0.221	0.029	0.272	0.370	0.002
OPP4.0	0.212	0.115	0.089	0.234	0.016	0.264	0.367	0.000
OPP4.5	0.249	0.136	0.095	0.276	0.000	0.280	0.425	0.000

Table 6.11 a Average defender weapon weights

Sz	MMBT	AFV	ATRS	MIT	SRAD	AHOW	RL	ATHEL
MGD2.0	0.022	0.158	0.410	0.086	0.000	0.110	0.289	0.375
MGD2.5	0.044	0.176	0.410	0.114	0.000	0.136	0.341	0.434
MGD3.0	0.084	0.166	0.367	0.141	0.000	0.131	0.355	0.416
MGD3.5	0.147	0.148	0.338	0.160	0.000	0.132	0.339	0.351
MGD4.0	0.198	0.122	0.287	0.157	0.000	0.137	0.341	0.294
MGD4.5	0.176	0.120	0.304	0.163	0.000	0.135	0.343	0.280
MGP2.0	0.006	0.143	0.378	0.064	0.000	0.096	0.227	0.286
MGP2.5	0.015	0.176	0.426	0.087	0.000	0.108	0.274	0.358
MGP3.0	0.031	0.191	0.427	0.110	0.000	0.135	0.317	0.384
MGP3.5	0.050	0.212	0.476	0.134	0.000	0.136	0.357	0.435
MGP4.0	0.058	0.208	0.486	0.172	0.000	0.125	0.378	0.434
MGP4.5	0.128	0.207	0.466	0.193	0.000	0.128	0.390	0.390
OGD2.0	0.051	0.112	0.457	0.092	0.000	0.080	0.290	0.455
OGD2.5	0.118	0.103	0.398	0.113	0.000	0.091	0.277	0.385
OGD3.0	0.178	0.076	0.290	0.116	0.000	0.102	0.271	0.259
OGD3.5	0.183	0.070	0.261	0.114	0.000	0.105	0.267	0.267
OGD4.0	0.144	0.068	0.247	0.116	0.000	0.112	0.268	0.262
OGD4.5	0.132	0.065	0.248	0.113	0.000	0.121	0.343	0.217
OGP2.0	0.018	0.118	0.477	0.071	0.000	0.068	0.260	0.388
OGP2.5	0.020	0.123	0.484	0.080	0.000	0.084	0.262	0.417
OGP3.0	0.062	0.126	0.494	0.113	0.000	0.082	0.305	0.412
OGP3.5	0.121	0.133	0.472	0.133	0.000	0.092	0.306	0.381
OGP4.0	0.166	0.123	0.466	0.145	0.000	0.097	0.314	0.349
OGP4.5	0.153	0.111	0.431	0.156	0.000	0.092	0.305	0.279

Table 6.11 b Average defender weapon weights (cont'd)

Sz	MMBT	AFV	ATRS	MIT	SRAD	AHOW	RL	ATHEL
MPD2.0	0.051	0.166	0.136	0.194	0.000	0.180	0.322	0.085
MPD2.5	0.081	0.162	0.142	0.226	0.000	0.161	0.372	0.100
MPD3.0	0.090	0.166	0.148	0.235	0.000	0.155	0.315	0.101
MPD3.5	0.151	0.158	0.135	0.247	0.000	0.170	0.342	0.069
MPD4.0	0.200	0.154	0.162	0.267	0.000	0.190	0.374	0.024
MPD4.5	0.237	0.156	0.156	0.284	0.000	0.184	0.405	0.000
MPP2.0	0.025	0.195	0.109	0.157	0.000	0.165	0.280	0.071
MPP2.5	0.033	0.225	0.156	0.207	0.000	0.170	0.361	0.084
MPP3.0	0.036	0.234	0.164	0.229	0.000	0.161	0.346	0.095
MPP3.5	0.040	0.240	0.179	0.256	0.000	0.185	0.365	0.079
MPP4.0	0.072	0.233	0.198	0.291	0.000	0.180	0.376	0.036
MPP4.5	0.122	0.243	0.217	0.334	0.000	0.194	0.421	0.002
OPD2.0	0.041	0.168	0.147	0.203	0.000	0.194	0.304	0.088
OPD2.5	0.076	0.177	0.150	0.230	0.000	0.177	0.354	0.085
OPD3.0	0.105	0.151	0.135	0.212	0.000	0.173	0.304	0.086
OPD3.5	0.161	0.155	0.151	0.237	0.000	0.204	0.361	0.078
OPD4.0	0.222	0.169	0.158	0.260	0.000	0.225	0.381	0.029
OPD4.5	0.213	0.172	0.163	0.286	0.000	0.249	0.416	0.002
OPP2.0	0.020	0.188	0.109	0.148	0.000	0.187	0.268	0.063
OPP2.5	0.024	0.235	0.153	0.204	0.000	0.188	0.329	0.086
OPP3.0	0.029	0.233	0.154	0.220	0.000	0.188	0.332	0.080
OPP3.5	0.070	0.235	0.166	0.255	0.000	0.194	0.362	0.058
OPP4.0	0.094	0.241	0.193	0.287	0.000	0.218	0.400	0.032
OPP4.5	0.142	0.248	0.213	0.318	0.000	0.240	0.430	0.000

Table 6.12 a Attacker:defender initial Combat Power Ratios (CPR) resulting with BAMS-based scoring systems and with the scores obtained from simulation experiments

Szenario	BAM-G Generic	BAM-G Kosmos	BAM A/D	BAM-G SM	Kosmos APP
OGP2.0	1.72	1.75	1.53	1.59	1.39
OPP2.0					1.41
MGP2.0				1.51	1.47
MPP2.0					1.39
OGD2.0				1.86	1.44
OPD2.0					1.43
MGD2.0				1.76	1.52
MPD2.0					1.43
OGP2.5	2.12	2.15	1.88	1.95	1.93
OPP2.5					1.63
MGP2.5				1.85	1.85
MPP2.5					1.64
OGD2.5				2.29	2.06
OPD2.5					1.90
MGD2.5				2.16	1.92
MPD2.5					1.89
OGP3.0	2.45	2.50	2.18	2.26	2.33
OPP3.0					2.12
MGP3.0				2.15	2.33
MPP3.0					2.05
OGD3.0				2.65	2.95
OPD3.0					2.68
MGD3.0				2.51	2.47
MPD3.0					2.43

Table 6.12 b Attacker:defender initial Combat Power Ratios (CPR) resulting with BAMS-based scoring systems and with the scores obtained from simulation experiments (cont'd)

Szenario	BAM-G Generic	BAM-G Kosmos	BAM A/D	BAM-G SM	Kosmos APP
OGP3.5	2.84	2.89	2.53	2.62	2.82
OPP3.5					2.45
MGP3.5				2.49	2.59
MPP3.5					2.37
OGD3.5				3.07	3.88
OPD3.5					2.89
MGD3.5				2.91	3.08
MPD3.5					2.90
OGP4.0	3.21	3.27	2.86	2.96	3.31
OPP4.0					2.59
MGP4.0				2.81	2.98
MPP4.0					2.69
OGD4.0				3.47	4.74
OPD4.0					3.36
MGD4.0				3.29	3.92
MPD4.0					3.41
OGP4.5	3.67	3.75	3.28	3.39	4.32
OPP4.5					3.06
MGP4.5				3.22	3.63
MPP4.5					3.06
OGD4.5				3.98	5.49
OPD4.5					3.82
MGD4.5				3.77	4.78
MPD4.5					4.07

The rank orders of the CPRs obtained for them are presented in Table 6.13.

272. Of the three scoring approaches not considering situational circumstances, the highest CPR results for BAM-G-Kosmos followed, in decreasing order, by BAM-G-Generic and BAM-A/D. The CPRs resulting for BAM-G-SM exceed those of BAM-G-Kosmos when the attacker is faced with a deliberate defense. In contrast, in case of a prepared defense the CPRs shift to the lower end of the spectrum. And given the degree of defense preparation, open terrain is more favourable for the attacker than mixed terrain, but more so in case of a deliberate than a prepared defense. However, it should be pointed out that this effect was reversed in experiments that featured attacks by mechanized infantry rather than armor (see Annex IV 3, Chapter 7).

273. Figure 6.7 shows that the average CPRs obtained with the APP-method from the KOSMOS experiments agree quite well with the CPRs resulting for the four scoring systems, in particular with those for BAM-G-SM. In case of a prepared defense, this agreement is better for mixed terrain (average deviation from the BAM-G-SM scores 6 %) than for open terrain (average deviation from the BAM-G-SM scores 11 %). Visibility conditions do not affect the average deviation to a measurable degree.

Table 6.13 Rank order of Combat Power Ratios (CPR) obtained from scoring approaches

terrain	defense	Rank Order*	Maximal Variation
open	prepared	BAGK>BAGG>**BASM**>BAAD	11 %
mixed	prepared	BAGK>BAGG>BAAD>**BASM**	14 %
open	deliberate	**BASM**>BAGK>BAGG>BAAD	18 %
mixed	deliberate	**BASM**~BAGK>BAGG>BAAD	13 %

* BAGG = BAM-G-Generic
BAGK = BAM-G-Kosmos
BAAD = BAM-A/D
BASM = BAM-G-SM

274. Similarly, for a deliberate defense under poor visibility conditions the average deviation of the CPRs obtained from the KOSMOS experiments from those obtained with BAM-G-SM is a mere 9 %. However, for a deliberate defense under good visibility conditions the deviations (in favour of the attacker) become significant, the more so the stronger the attacker. This effect is more pronounced for open terrain (maximal deviation 35 %) than for mixed terrain (maximal deviation 27 %).[6]

275. Thus, we may state that the investigated scoring systems have not been falsified by the simulation experiments, except perhaps for situations featuring a deliberate defense under good visibility conditions when the initial attacker:defender combat power ratio exceeds a value of about 3:1. In particular, the BAM-G scores in conjunction with the situational multipliers of RAND's situational force scoring system seem to provide good measures for computing combat power ratios in main-thrust sectors when a mechanized defense is confronted with an armored attack.

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[6] Of course, these deviations may be due to different perceptions about the circumstances pertaining to the term "deliberate defense" rather than to fundamental differences in assessments embedded in the BAM-G-SM scoring system on one and and in the KOSMOS experiments on the other. For example, it might well be that a deliberate defense in the KOSMOS experiments is closer to what the judgement underlying RAND's situational multipliers considers a hasty defense. Thus, as a first step in the validation of a scoring system one needs to make certain that the situational parameters for the simulation experiments are consistent with the definitions embedded in the scoring systems's situational multipliers.

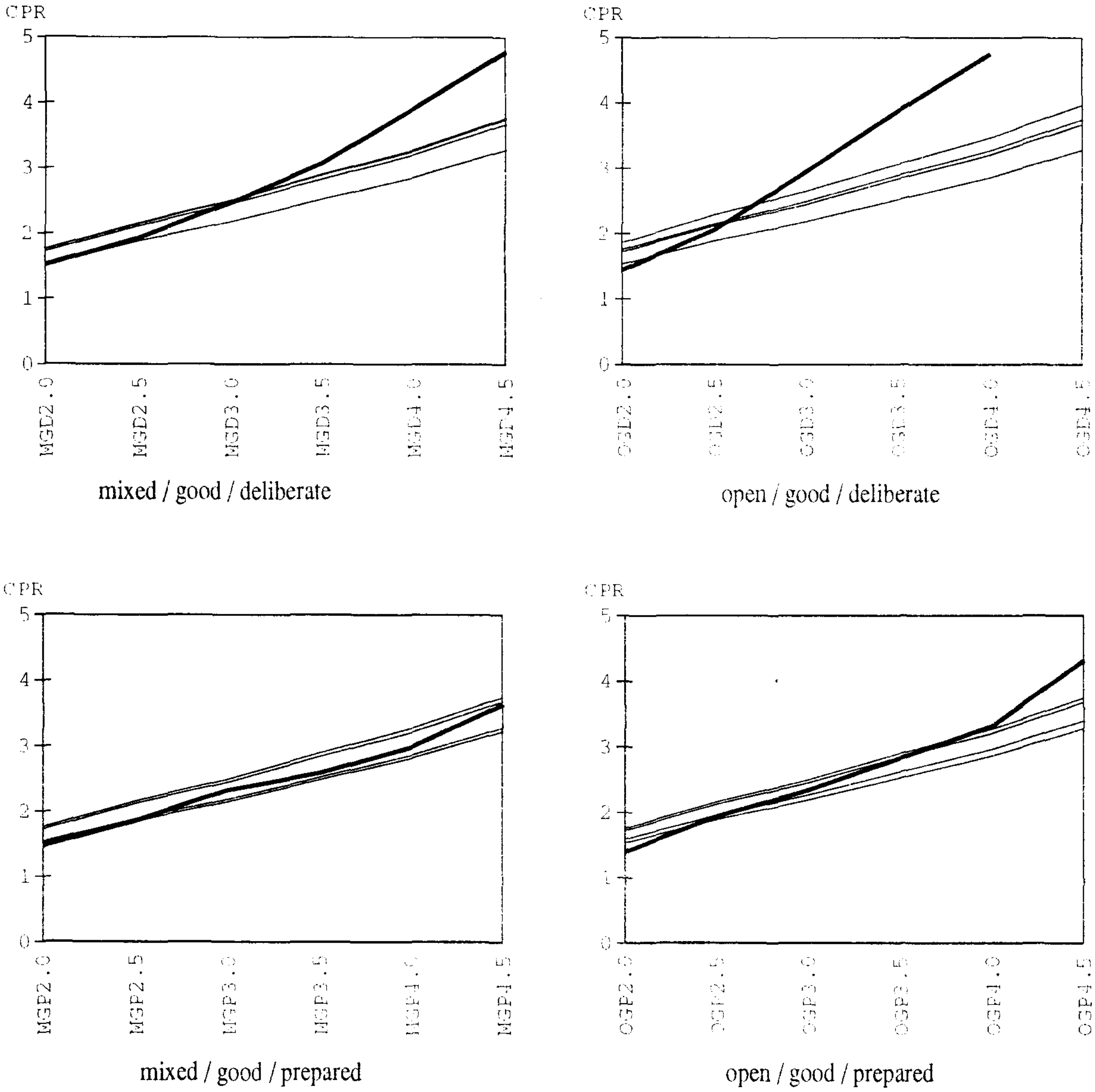

Figure 6.7 a: Attacker:defender Combat Power Ratio (CPR) as a function of the initial attacker:defender strength for different (terrain, visibility, defense) situations

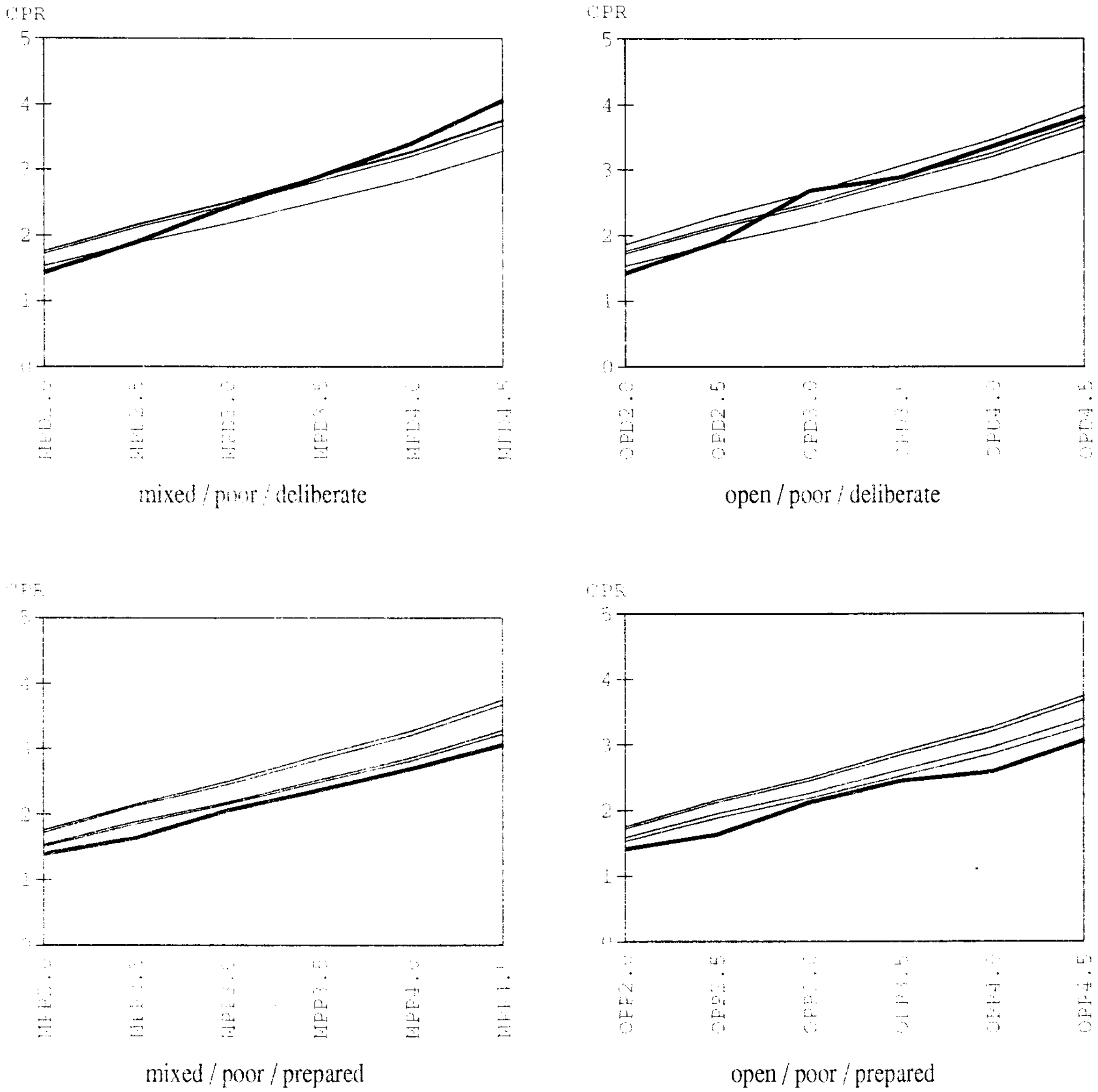

Figure 6.7 b: Attacker:defender Combat Power Ratio (CPR) as a function of the initial attacker:defender strength for different (terrain, visibility, defense) situations (cont'd)

CHAPTER 7

RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

7.1 APPROACH AND MOTIVATION

276. The RSG's work seeks to bring into the NATO debate on conventional warfare some new thinking on what forms of stability the international community should pursue. Previously security was thought of mainly in terms of a perilous balance. Many were concerned that this balance could be upset too easily by military build-ups in peacetime, or by precipitous escalation in crisis. The RSG has envisaged a situation where the international security situation is such that the possibility of successful aggression by any party is minimised. The RSG has taken the first step to look at this, and the RSG hopes to raise awareness within the analytical community of the possibility of achieving more stable relationship between nations. The RSG has considered the influence of a regional collective defence or security organisation and the influence that the international community may have on regional stability through an international force.

277. The RSG's work has laid down a foundation for attacking problems of military-political nature, which was largely absent from previous DRG sponsored studies. The RSG has shown how an analytical approach to this type of problem is possible.

278. RSG.18 has formulated a definition of stable defence. A party has established a *unilateral stable defence* against the other parties within a region if the party is confident that: the other parties have no intention of launching an attack, or the other parties cannot accept the risk of attacking, or any attack can be repelled. If all parties within a region have established a unilateral stable defence, the region is a *multipolar stable defence system*.

279. The RSG has developed a mathematical framework for analysing stability that inter-relates intentions, risk aversion, and military power. This framework integrates the use of multiple dissimilar models, and combines static and dynamic approaches. It was used to evaluate notional conflict situations and to provide first estimates of the defence capabilities required to establish a stable multipolar system.

280. Conclusions and recommendations derived from the RSG.18 study are presented in this chapter. First, general conclusions are drawn from the analysis of the analytical multipolar stability models. Then specific conclusions are derived from testing stability hypotheses by means of battle simulation experiments.

7.2 ANALYTICAL FINDINGS

281. It should be noted that, within the time and resources available to RSG.18, analysis and hypotheses testing was limited to a few scenarios only that were compatible with the models and experiments that the participating institutions were ready to contribute. Nevertheless, the results obtained are judged to be significant and to provide a sufficient basis for drawing some substantial conclusions.

7.2.1 General Conclusions

282. The RSG's model analysis suggests that the risk attitudes of the parties have a powerful influence on stability. In particular, if the parties assess other, potentially hostile, parties as highly risk averse, and are willing to accept some degree of risk themselves, then stability can be obtained at modest force levels, and without extensive force re-structuring. If, however, the opposite risk attitudes prevail, that is, if the parties assess other parties as not very risk averse, and insist on very high confidence that their own defences will hold if tested, then the result is instability almost regardless of plausible force levels or equipment types.

283. This conclusion stems in part from the RSG's finding that purely defensive[1] forces are rather infeasible, at least within the foreseeable future. If feasible and cost-effective purely defensive forces could be identified, then stability could be obtained at plausible force levels regardless of the parties' risk preferences. The RSG's simulation experiments, however, failed to provide any evidence that such purely defensive forces could be created.

284. The absence of purely defensive forces makes it impossible to compensate unilaterally for imbalances in the military capabilities of individual states in a multipolar international system. To the extent that purely defensive forces cannot be identified, it therefore follows that it would never be possible to escape the security dilemma: that is, the problem of neighbours interpreting defensive improvements as threatening.

285. This implies that some external assistance to defenders would be required to ensure stability. This external assistance could take the form of collective defence arrangements, international military forces, ad-hoc coalitions, or some combinations of these. Of course the nature, charter, or membership of such organisations was beyond the scope of the RSG's analysis; nonetheless the results obtained point to the necessity of some such means if a high degree of multipolar stability is to be attained.

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[1] Purely defensive, reactive, or non-offensive defence (NOD) systems are all terms used for systems which only can be used for strictly defensive purposes.

286. While the creation of collective defence or security arrangements capable of matching aggressive armies with superior force would in theory provide such means of compensation, the nature, charter or membership of such an organisation is beyond the scope of the RSG. An organisation can contribute to security enhancement while alleviating the security dilemma through appropriate organisational means, such as a transnational composition of military units and a multinational division of labour, which may make offensive operations difficult without the unanimous agreement of all parties.

287. Operational concepts and doctrine also have a major effect on stability. In particular, shallow, passive defensive doctrines make successful defence extremely difficult over a wide range of force ratios or equipment types, and are highly destabilizing. On the other hand, a mobile defence in some depth having the capability for quick counter-concentration is rather stable in comparison to a static forward defence.

288. However, unless counter-concentrations can be effected by highly accurate long-range fire, they necessitate a high degree of operational mobility for the defender forces in order for stability to obtain. This may give rise to perceptions of offensive intent. Yet, if all parties in a region dispose their forces in this manner, there is no reason to believe that this will increase the ability of any one to attack any of the others. Moreover, if all parties in a region are given faster transportation systems there is again no reason to believe that this will on balance increase the capability of attackers more than the capability of defenders.

289. Offensive air capabilities tend to be destabilizing unless compensated by air defenses capable of protecting offensive air systems against air strikes, thus removing a pre-emption bonus, and capable of neutralizing them when they attack land force assets and communication lines of the defender only. Thus, in order to favour the defending side air defenses should be either stationary or have mobility limitations designed into them so that they may not provide protection for ground forces advancing rapidly on enemy territory.

7.2.2 Specific Conclusions

290. With a few exceptions, the simulation experiments conducted by RSG.18 for testing stability hypotheses featured break-through battles on divisional or lower levels. It should be noted that the hypotheses could be tested in a few scenarios only. Nevertheless, the results obtained have been significant and are sufficient to draw the following conclusions.

291. In the evaluation of the experiments all options favouring the defender more than the attacker are assumed to have stabilizing effects, and vice versa. If several options are available, the optimal one for the attacker is the most destabilizing one, and for the defender the most stabilizing one.

7.2.2.1 Combat Units

292. There are no type of combat units among those investigated that are purely defensive or offensive.

293. The analyses conducted failed to sustain the hypotheses that infantry is stabilizing and armour is destabilizing. There is no evidence that tank-heavy formations significantly favour the aggressor while infantry-heavy formations favour the defender. The extent to which any of the investigated combat units performs better in defensive than in offensive operations, or vice versa, depends on the prevailing situational parameters (terrain, visibility, combat mode, degree of defense preparation, etc.)

7.2.2.2 Infantry

294. Even in modern warfare, infantry seems to be quite capable of offensive operations when visibility is poor and/or terrain is rough. In that case, the probability of accomplishing a successful break-through is higher for infantry-heavy forces than for tank-heavy forces. A break-through is virtually certain if the defender has no time to prepare positions (deliberate defense).

7.2.2.3 Tanks

295. Tanks represent a formidable defensive system, especially when visibility is good and terrain favourable to armoured operations. In fact, a comparison of the experiments involving tank-heavy and infantry-heavy forces on both sides indicates that a defender benefits more than an attacker from adding tanks to his force.

7.2.2.4 Artillery

296. In addition to situational conditions, the stabilizing effects of artillery depend primarily on whether or not there is a defense advantage in the sense that defender units are less susceptible to artillery effects than attacker units because of concealment and cover. In that case, artillery tends to be stabilizing. However, whether this remains true if smart artillery munitions are available rather than the HE-munitions used in the experiments needs to be investigated.

7.2.2.5 Helicopters / Air Defense

297. Similar to artillery, attack or anti-tank helicopters contribute to stability only if there is a significant advantage for the defending side from concealment and cover of targets as well as from air defense. Thus, highly mobile short-range air defenses favour the attacker more than the defender. In contrast, non-mobile long-range air defense systems that

cannot escort armour, but have sufficient range to cover the area of defense operations, are stabilizing.

7.2.2.6 Mines

298. In many experiments, mines deployable by rocket artillery have favoured the attacker more than the defender. This was because they delay the movement of the defender's reserves. Thus, the reserves were not available in time to be of any significant benefit to the defender. Although the second echelon of the attacker was delayed as well, the lack of reserves is more detrimental to defense operations than the lack of the second echelon forces to attack operations.

299. Even though available as an option in the simulation models, conventional laying of mines by engineers was not observed in any of the experiments. This is because the time requirements for the conventional deployment always exceeded time available for defense preparations during the battle. Thus, in order to contribute to stability, mines must be deployed early as part of the initial defense preparations in anticipation of an attack.

7.2.2.7 Decoys

300. The use of decoys increases the military capability for the defender and the attacker. The defender and the attacker may gain equally from employment of decoys. However, the ability to deploy decoys may differ for the defender and the attacker. A defense from prepared positions will provide the best possibility to insert decoys in a way that resembles to real units. This possibility is not always available to the attacker. The great advantage of deploying decoys and the greater possibility for the defender to do so shows that the use of decoys is advantageous to the defense. In this way, decoys will have at least a marginal enhancing effect on stability.

7.2.2.8 Thinned-out Battlefield

301. On a thinned-out battlefield the capability for an immediate response of the defender to enemy actions is extremely important for stability, i.e., time and place of attacks must be anticipated in time so the defender does reach prepared positions before the attacker arrives there. In other words, for a stable defense under thinned-out battlefield conditions real-time reconnaissance, high mobility, and the means to delay and canalize attacks are indispensable.

7.2.2.9 Tactical Attack Velocity

302. In all experiments, a certain defense advantage was assumed to exist. Thus, the longer a battle lasts the more the defender may benefit from this advantage. Therefore, decreasing the attack velocity on the tactical level contributes to stability.

7.2.2.10 Visibility

303. The experiments of RSG.18 indicate that visibility is not a major factor affecting armoured battles. However, the more infantry is involved the more critical a factor visibility becomes. Poor visibility conditions are highly essential for the success of infantry attacks. A deliberate armoured defense stands almost no chance to prevail when attacked by infantry when visibility is poor. However, when attacked by armour, poor visibility benefits an infantry-heavy defender more than the attacker.

7.3 RESERVATIONS

304. Finally, it should be re-emphasised that the military influence on stability is only one factor amongst many, although it is a major one. The very important non-military issues of stability are a result of many factors that depend on particular historical, social, cultural, economic, etc., conditions of each party in the region, and in particular the differences between the parties with respect to these factors. Moreover, the outcome of a military conflict is not determined only by equipment and manpower but is also strongly affected by other factors such as leadership, training, morale, although these factors could not be incorporated explicitly into the analysis.

7.4 RECOMMENDATIONS

305. The inability to overcome the security dilemma and provide stability through purely defensive military systems or force design constitutes an important motivation for more careful study of the potential of regional collective security.

306. Likewise, options for effective international forces to provide the necessary military capability for a stable regional defence system warrant further study as a matter of priority. This should include consideration of the crisis management system within which this force would be intended to operate. It would be useful to continue and expand the experimental research initiated by RSG.18 on a collaborative basis to aid the design of military forces that would implement any of the various options.

307. The importance of doctrinal choices for stability suggests that doctrinal interchange between nations be used as means of ensuring that sound defensive doctrines are adopted as widely as possible. Therefore, international doctrinal collaboration in the interests of more effective defensive force employment should be encouraged and expanded.

308. Of course the conclusions reached here necessarily depend on a partial set of hypotheses tests. Whilst the RSG feels that the tests conducted represent a reasonable basis for reaching these conclusions, nevertheless a more comprehensive set of tests would provide greater confidence and warrants further analytic effort.

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ANNEX I

RESEARCH STUDY GROUP 18 ON STABLE DEFENCE

AC/243(PANEL 7/RSG.18)

TERMS OF REFERENCE

I. ORIGIN

A. Background

1. The CFE Treaty, signed in November 1990, will bring about approximate parity between NATO and the former WTO at significantly reduced levels of the principal conventional weapon system categories. However, parity alone does not necessarily imply military stability in the sense that the military system is able to repel any possible attack. In addition, the dissolution of WTO makes the military situation in Europe multipolar, rendering parity between the former grouping obsolete. There is a need to identify what constitutes stable defence in the new environment.

B. Military Significance

2. The RSG will explore the feasibility, and potential obstacles to the achievement, of generic stable defence structures, and identify essential characteristics of such structures. The results of this effort could become a better understanding of possibilities for creating stability in future defence concepts and structures.

II. OBJECTIVES

3. The RSG will apply a top-down approach in developing an analytical framework for analyzing the fundamental requirements for, and constraints on, military forces to assure a stable defence in a multipolar and a bipolar context.

4. To explore concepts of military stability and methodologies to identify essential characteristics of force structures, enhancing stability, related to future European security needs.

5. The RSG will consider generic structures and scenarios of relevance to the European situation. The RSG will focus on conventional land forces with considerations to the impact from other assets, especially air.

6. The RSG will, where necessary, define and perform closed combat simulation experiments for combat situations in order to evaluate possible generic military structures enhancing stability.

7. The RSG aims to complete and report the study within two years. However, due to the complexity of the subject matter and dependent on the extent of national involvement some extension cannot be excluded.

III. RESOURCES

A. Membership

8. This will include analysts and military experts with a background in security policy, arms control, force structure planning, combat modelling and developing concepts of operations.

B. Special Needs

9. Access to existing, relevant, national studies is required. The effectiveness of new military structures has to be analyzed by use of available national computer models, using national data and computer time.

IV. SECURITY LEVEL

10. Participants will need access to information up to and including NATO SECRET.

ANNEX II

RESEARCH STUDY GROUP 18 ON STABLE DEFENCE

AC/243(PANEL 7/RSG.18)

OUTLINE PROGRAMME OF WORK

I. MAJOR ITEMS

1. The following major items are identified to meet the requirements of the TOR:

(a) survey of relevant literature and analytical models concerning stable defence, and in the light of these formulate working hypotheses on stable defence;

(b) development of an analytical framework for a top-down analysis of the fundamental requirements to, and constraints on, military forces to assure a stable defence in a multipolar context and bipolar context; formulation of measures of effectiveness;

(c) identification of principles of military factors (e.g. force employment, system characteristics and force structures) enhancing stability;

(d) effectiveness evaluation of some generic military structures in combat situations based on existing studies and national combat models;

(e) modeling validation of generic military structures in a bipolar context;

(f) modeling validation of generic military structures in a multipolar context;

(g) reporting.

II. TIME SCALE

2. From the first meeting of the RSG the time scale for completion of the major items is scheduled as follows:

(a-c) after 8 months

(d) after 18 months

(e-g) after 24 months

III. MILESTONES

3. Essential milestones occur when the RSG has accomplished items (c), (d), (e), (f) and (g).

IV. NATIONS PARTICIPATING

4. Canada, Denmark (pilot), France, Germany, Greece, the United Kingdom, The United States and STC will participate in this study and Italy, the Netherlands and Norway are considering participation.

V. NATIONAL AND AGENCY CONTRIBUTIONS

5. Denmark will contribute with the DEFENCE DYNAMICS model to be used for evaluation of stable defence structures in combat situation, and a possible analytical framework for multipolar stability.

VI. EDITING EQUIPMENT

6. Exchange of information will take place via ASCII files or hardcopies.

VII. STATUS

7. The RSG will remain open.

VIII. PARTICIPANTS

CHAIRMAN

MEMBERS

ANNEX III

NONMILITARY FACTORS INFLUENCING MULTIPOLAR STABILITY

Contents

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1. INTRODUCTION

1. With the emerging new political world order, a new distribution of military power is arising. This will inevitably have an impact on national defence policy, changes in the force structure, etc., and although some traditional missions, (e.g., territorial defence, UN peace making/keeping, and NATO participation) may be the same, the way of carrying out these tasks will change.

2. These changes are due to the widening theatre of operations, the types of conflicts and modes in which they are fought, and the spread of new weapons technology even to underdeveloped countries. Not only could these weapons be used to settle local disputes but also, given the weak command and control structure in these countries, there is a chance that such weapons could fall in the hands of terrorist groups.

3. The new international order will not necessarily be a peaceful or stable one. Indeed, a multipolar system (in comparison to the old bipolar one) with its many degrees of interactions, may tend to be inherently unstable. Thus, greater levels of uncertainty and even violence may be the norm in some parts of the world, and international institutions may increasingly be called upon to respond to regional aggression.

4. However, to respond effectively, potential military conflicts cannot be analyzed in isolation. Events (e.g., political, economic, and social instabilities) preceding military actions are important indicators to determine the root of the tension between opponents, the intensity of the crisis, and the magnitude of an eventual conflict. In 1829 already, Karl von Klausewitz [1] noted the strong relationship between politics and war when he said: "Der Krieg ist nichts als eine Fortsetzung des politischen Verkehrs mit Einmischung anderer Mittel".

5. From this it can be concluded that the causes leading to a political crisis must be understood so that international organizations can effectively respond, either in advance to settle disputed issues and suppress military actions, or if this fails to take an active part in dealing with the emerging conflict. Thus, the planning of future defence policies and force development has to start with conflict analysis to determine the cause, scope, frequency, density, and location of future conflicts.

6. Based upon this knowledge, national forces may be restructured to meet the new requirements in the areas of weapon systems, transport, logistics, man power distribution amongst the services, and investment management. In this respect, conflict analysis may help to minimize the uncertainty of assessing the necessary new force structure to safeguard peace

and to ensure conditions for effective crisis management to resolve the tensions with the least military involvement.

7. This paper describes a model to assess the conflict dynamic of a geopolitical region. Apart from two military indicators there are seven non-milityary criteria included in the model which can influence not only the start of a crisis, but also the progress of a military conflict.

2. CRISIS AND CONFLICT CRITERIA

8. In the past, several mathematical theories [2-5] were formulated to describe the international relations of countries and the conditions leading to the outbreak of conflicts. These models dealt largely with bipolar systems where third parties would influence a conflict through one or the other main actor (which may be a faction, single country, or an alliance).

9. The new multipolar world, however, with its complex structure requires a different mathematical approach to conflict analysis [6-9]. The objective of this paper is to assess the influences of non-military factors contributing to the crisis and military conflict potentials of an entire geopolitical region. Countries, subject to analysis, are rated against a number of non-military and military criteria such as external relations, internal situations, defence capabilities, etc. The rating matrix thus obtained is analyzed by a discriminant procedure which displays a comparative measure of conflict potentials of the countries in a region. This could provide policy makers with systematic and consistent global assessments at specific times, and contingency planners with the level of effort needed for peacekeeping or peacemaking operations.

10. Nine major and numerous subcriteria have been selected against which all countries subject to analysis are rated. These criteria describe country external relations and internal situations.

11. Let the ratings for the nine criteria be described by nonsymmetric matrices $[\mathbf{X}]_k$, k=1,2,...,5 of size mxm where m denotes the number of countries to be analyzed. The ratings for each of the criteria are given on a scale from A to F and describe a situation with respect to the overall capability or size of a country.

Rating= A: no friction; fully compatible policies or systems; no pressure; stable; fully adequate to defend country; low attack capability, etc.

Rating= F: critical friction; incompatible policies or political systems; violence; heterogeneous; high systemic pressure; defence not adequate; high attack capability, etc.

12. Each of the 9 main criteria were assessed through a number of subcriteria as given below:

13. **Unresolved Bilateral Issues.** Disputes in a number of areas which may include:

- export of ideologies
- influx of refugees
- treatment of ethnic groups outside the country
- territorial and resource claims
- border disputes
- international environmental and ecological issues
- state-sponsored terrorism
- support for separatist movements and revolution in another country
- national security; arms build-up above national defence requirements
- political vulnerability and isolation

14. Numerical values in the rating matrix must reflect the physical size of the issue and the magnitude of the attached political importance (whether real or imaginary) in comparison to a suitable measure. The size and resources of a disputed territory, for example, can be related to the total size and resources of the country. More difficult is the rating of the export of ideologies, terrorism, or the treatment of ethnic groups in another country. The element X_{24}=E in Table 1, for example, denotes the crisis level of country B towards country D. Note that X_{42}=A because of the lesser importance to D with respect to its overall problems and commitments.

15. **Economic Factors.** This criterion describes the dependence of the economies which may include:

- dependence on vital imports as energy, food, strategic resources, water
- technology transfer
- trade imbalance
- financial aid and dependence
- differences in the GDP with trading partners or neighbouring states
- reliability as trading partner

16. The elements in these input matrices, may be multiplied by a "hurt" factor expressing the socio-economic vulnerability of a country. It depends on the ethnic attitude of the population and the amount of hardship they can endure.

17. **Racial Relations.** This criterion includes:

- historical animosity and conflict frequency
- compatibility in racial attitudes (expressible as psychic distance between two ethnic groups)

- intellectual distance (diminishes with increasing similarity of rational processes, educational standardizations, communication)
- religion
- compatibility in living standards

18. **Defence Capabilities.** Numerical values for these rating matrices depend on the ratio *defensive force i/ offensive force j* since an inadequate defence capability may invite a military solution of a conflict. The force ratio may also take into account third party defence treaties which also includes *out-of-region* actors and international organizations. Clearly, if there are no external crisis problems, the associated defence need is zero, no matter what the force ratio is.

19. **Attack Force Potential.** A potential threat of attack is present if there is a crisis between two actors. The threat of attack is primarily governed by the force ratio *offen-sive force i/ defensive force j, which* also includes third party treaties. Apart from the force ratio and the ethnic attitude, many other factors have to be considered such as:

- militarisation degree
- biological and chemical weapons
- nuclear weapons
- sizes of active ground, air and sea forces
- degree of training of active forces
- level of battlefield experience
- leadership; risk-taking propensity of commanders
- reserve force size and degree of training
- mobilization potential
- command, control and communication
- sensor and intelligence capabilities
- proximity to home territory (length of supply lines)
- environmental factors (terrain, weather, local resources, diseases)
- supply support, logistics
- degree of weapon systems integration
- weapon system capabilities
- Industrial and technological bases
- conflict sustainability

20. Clearly, if there are no external crisis potentials, then there is no associated attack potential. It should be noted that the attack force ratio is not necessarily the inverse of the above defence force ratio because the former includes the capability to reach the target country.

21. There are four country-internal criteria which, however, under some circumstances may be not quite independent of the internal situations in other countries. For example, the Islamic Revolution in Iran has an impact on the internal political structure of other governments in the Middle East as far as Egypt and even Morocco. The diagonals in

these matrices are the internally generated crisis potentials, while all other elements are external influences. With this, other actors may influence the internal situation in a positive or negative way.

22. **Political Stability.** Political instability of a country may lead to internal conflicts (e.g., political factions inside the government working against the President). Indicators of potential conflicts are:

- form of government and ideology
- stability of government (e.g., number of factions)
- separatist movement
- armed political opposition; political terrorism against each other or against the centre
- military or paramilitary involvement in internal security

23. **System Pressure.** This criterion assesses the pressure upon the population which may lead to internal violence. Indicators may include:

- human rights and freedom of expression
- environmental risks and health
- distribution of wealth
- economic reforms
- diminishing resources and revenues
- military or paramilitary involvement in internal security
- organized crime

24. **Systemic Frustration.** The elements in this matrix are measured by: social frustration = S/W, where S= social satisfaction, and W= social want. Thus,

- no frustration= high S/ low W
- low frustration= low S/ low W
- high frustration= low S/ high W

25. As a starting point, the social frustration can be taken as a function of the ratio *GDP/capita*. From economic statistics [10], the following global rating scale can be designed to generate numerical values for this criterion:

GDP/capita (in US$*1000)	<1	1-2	2-4	4-7	7-10	10-14	>14
Rating	F	F	D	C	B	A	0

26. Rating C separates developing countries as, for example, Somalia ($150), Tajikistan ($2300), and Kazakhstan ($3700) from the richer ones. The middle ground (C) is occupied by semi-industrialized countries such as the Ukraine ($4700) or Lithuania ($5500).

27. **Demographic Structure.** This criterion covers the non-homogeneity of the population via the factors:

- ethnicity
- language differences; (official language, others)
- rivalry in religions; (state religion, others)
- education differences
- social groups bound by same social want

3. RATING MODEL

28. An intermediate step towards the computation of crisis and conflict potentials is the formation of a decision matrix [Z] which contains the data of all 9 rating matrices [X]. This can be done by reducing the matrices $[X]_i$ to vectors $\{Y\}_i$ by a suitable linear combination rule.

29. Let the symbol $\cup$ denote the combination of all ratings X_{ij}, j=1,2,...,m, i≠j with respect to actor i. Then the total problem $\mathbf{Y}_k$ of criteria k at any time can be expressed by the first elements of a Maclaurin series as:

$$\{Y_i\}_k(t) = w_k \bigcup_{j=1}^{m} \left(\left[X_{ij}(t=0)\right]_k + t\left[x'_{ij}(t=0)\right]_k + \frac{t^2}{2}\left[x''_{ij}(t=0)\right]_k \right)$$

$$i = 1,2,\ldots,m \qquad k = 1,2,\ldots,n$$

where
w_k= weighting factor of criterion k
t=time
x'_{ij}= slope of X_{ij} estimated at the present time t=0
x''_{ij}= change of the slope estimated at present time

30. The 9 vectors {Y} are assembled into the matrix [Z] which then is treated by a multicriteria decision model [7] to yield the relative crisis and conflict potentials of the countries in a region.

4. INFLUENCE OF NON-MILITARY FACTORS

31. A computer program, termed ReCCA (Regional Crisis and Conflict Analysis) was written in Fortran to execute the model described in [7]. To demonstrate this model, let there be a geopolitical region consisting of 15 countries. The objective is to compute the crisis and military conflict potentials of each country relative to the others. By varying the actions of some actors (i.e., countries), the regional crisis and conflict potentials

may change and from this, the influence of the non-military factors can be deduced (see also Ref.11).

32. As a first result, Table 2 depicts the crisis potentials of these 15 countries for 1992 and 1996 (the diagram is to be read as: potential of actor in row i with actor in column j). These potentials were computed by using all non-military criteria and were summed over the individual potentials of each country. From this table it is evident that country D has non-military problems with most of the other countries in that region. Note, that the diagonal in Table 2 denotes country-internal problems.

33. Table 3 shows the result for the military conflict potentials which includes all 9 criteria. Except for country D, and perhaps for country F, the other ones do not possess large offensive capabilities in order to "resolve" some bilateral problems by means of military "solutions". Thus, although problems amongst the 15 countries are evident from Table 2, the conflict probability is rather low in many cases.

34. In a final step, the crisis and conflict potentials can be classified according to their magnitude. Table 4 depicts the total conflict potential of a country with respect to all othgers for 1996. The conflict potentials are grouped into classes where class 1 denotes a high potential while class 15 indicates a very low potential. The conflict potential of country D, for example, is very high because of the many small and medium large unresolved issues (foremost ethnicity, national border disputes, and economics) it has with everyone of the other 14 states.

35. In above example, the reason for the high conflict potentials in this region is due to political and economic problems. As a hypothetical case, let the political problems amongst the 15 states be reduced from the level shown in Table 1 to that of Table 5. Let there also be some bilateral economic treaties which decreases the present economic problems given in Table 6 to the level stated in Table 7. With this, other criteria such as the internal political situation, the systemic frustration, and the ethnic relations may also change to reflect the improved bi-lateral relations.

36. The influence on the military conflict potential is depicted in Figure 8. The conflict potential of country D is not reduced much due to the accumulations of a large number of small problems with the other 14 states. Most of the other, smaller states, however, show reduced military conflict potentials with their respective neighbours.

5. CONCLUSIONS

37. The generic example given in this paper demonstrates the significant influence of non-military factors on conflict potentials. Some examples of the conflict potentials of geopolitical regions are given in [6-8]. The influence of non-military factors upon

the conflict development was already recognized by von Klausewitz but is even more pronounced in the new multipolar world were the global politics and the global economy are decisive factors in internal matters of countries and the bilateral relations between them.

38. A large amount of input is required to execute the model, but, this has the advantage that the input elements describe only small and independent bits of a complex situation which are easier to comprehend. Also, some errors, made by the judgemental conversions of observations into numerical values, have only limited local effects.

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Table 1: Unresolved Bilateral Political Issues of Countries A to O

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
--	+0	+0	+D	+A	+0	+0	+0	+0	+0	+0	+0	+0	+0	+0	A
+0	--	+0	+E	+A	+0	+0	+0	+0	+0	+0	+0	+0	+0	+0	B
+0	+0	--	+D	+0	+0	+0	+0	+0	+0	+0	+0	+0	+0	+0	C
+A	+A	+A	--	+B	+D	+A	+C	+B	+C	+B	+A	+A	+B	+A	D
+A	+A	+0	+A	--	+C	+0	+0	+0	+0	+0	+0	+0	+0	+0	E
+0	+0	+0	+E	+B	--	+B	+0	+0	+0	+0	+0	+0	+0	+0	F
+0	+0	+0	+C	+0	+B	--	+0	+0	+0	+0	+0	+0	+0	+0	G
+0	+0	+0	+D	+0	+0	+0	--	+A	+B	+0	+0	+0	+0	+0	H
+0	+0	+0	+B	+0	+0	+0	+0	--	+F	+0	+0	+0	+0	+0	I
+0	+0	+0	+B	+0	+0	+0	+0	+F	--	+0	+0	+0	+0	+0	J
+0	+0	+0	+B	+0	+0	+0	+0	+0	+0	--	+B	+B	+A	+B	K
+0	+0	+0	+B	+0	+0	+0	+0	+0	+0	+B	--	+C	+0	+0	L
+0	+0	+0	+B	+0	+0	+0	+0	+0	+0	+B	+B	--	+B	+C	M
+0	+0	+0	+B	+0	+0	+0	+0	+0	+0	+A	+A	+B	--	+B	N
+0	+0	+0	+B	+0	+0	+0	+0	+0	+0	+B	+A	+C	+B	--	O

Table 2: Bilateral Internal and External Crisis Potentials for 1996

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
A	D	.	.	D	.	.	.	.	.	.	.	.	.	.	.
B	.	F	.	F	B	A	.	.	.	.	.	.	.	.	.
C	.	.	F	F	.	A	.	.	.	.	.	.	.	.	.
D	.	B	A	D	B	D	A	D	A	C	.	B	B	C	B
E	B	B	.	B	C	C	.	.	.	.	.	.	.	.	.
F	.	.	.	F	B	F	B	.	.	.	.	.	.	.	.
G	.	.	.	D	.	C	E	.	.	.	.	.	.	.	.
H	.	.	.	F	.	.	.	F	B	C	.	.	.	.	.
I	.	.	.	B	.	.	.	A	E	F	.	.	.	.	.
J	.	.	.	C	.	.	.	.	F	F	.	.	.	.	.
K	.	.	.	D	.	.	.	.	.	.	C	C	C	B	C
L	.	.	.	C	.	.	.	.	.	.	C	E	D	A	C
M	.	.	.	C	.	.	.	.	.	.	C	B	F	C	D
N	.	.	.	C	.	.	.	.	.	.	B	A	D	F	C
O	.	.	.	C	.	.	.	.	.	.	C	A	D	C	F

Table 3: Bilateral External Conflict Potentials for 1996

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
B	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
D	.	B	A	.	A	D	A	D	A	C	.	A	B	C	B
E	A	A	.	.	.	.	.	.	.	.	.	.	.	.	.
F	.	.	.	D	B	.	B	.	.	.	.	.	.	.	.
G	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
H	.	.	.	.	.	.	.	.	.	B	.	.	.	.	.
I	.	.	.	.	.	.	.	.	.	E	.	.	.	.	.
J	.	.	.	.	.	.	.	.	D	.	.	.	.	.	.
K	.	.	.	.	.	.	.	.	.	.	.	C	B	.	C
L	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M	.	.	.	.	.	.	.	.	.	.	B	B	.	C	D
N	.	.	.	.	.	.	.	.	.	.	.	.	B	.	C
O	.	.	.	.	.	.	.	.	.	.	A	.	B	C	.

Table 4: External Conflict Potentials for 1996

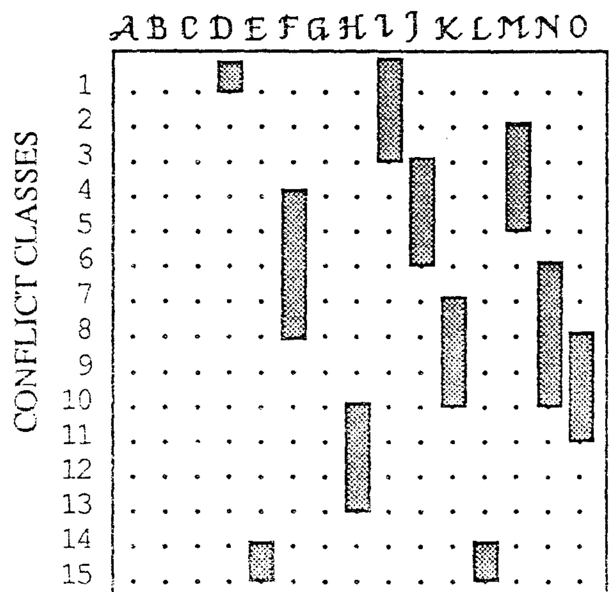


Table 5: Reduced Political Problems Between the Countries

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
--	+0	+0	+C	+A	+0	+0	+0	+0	+0	+0	+0	+0	+0	+0	A
+0	--	+0	+C	+0	+0	+0	+0	+0	+0	+0	+0	+0	+0	+0	B
+0	+0	--	+C	+0	+0	+0	+0	+0	+0	+0	+0	+0	+0	+0	C
+A	+A	+A	--	+A	+C	+A	+B	+A	+B	+A	+A	+A	+B	+A	D
+0	+0	+0	+A	--	+B	+0	+0	+0	+0	+0	+0	+0	+0	+0	E
+0	+0	+0	+C	+A	--	+A	+0	+0	+0	+0	+0	+0	+0	+0	F
+0	+0	+0	+C	+0	+B	--	+0	+0	+0	+0	+0	+0	+0	+0	G
+0	+0	+0	+C	+0	+0	+0	--	+A	+A	+0	+0	+0	+0	+0	H
+0	+0	+0	+A	+0	+0	+0	+0	--	+E	+0	+0	+0	+0	+0	I
+0	+0	+0	+B	+0	+0	+0	+0	+E	--	+0	+0	+0	+0	+0	J
+0	+0	+0	+A	+0	+0	+0	+0	+0	+0	--	+A	+A	+A	+A	K
+0	+0	+0	+A	+0	+0	+0	+0	+0	+0	+B	--	+B	+0	+0	L
+0	+0	+0	+B	+0	+0	+0	+0	+0	+0	+B	+B	--	+B	+B	M
+0	+0	+0	+B	+0	+0	+0	+0	+0	+0	+A	+A	+B	--	+B	N
+0	+0	+0	+A	+0	+0	+0	+0	+0	+0	+B	+A	+B	+B	--	O

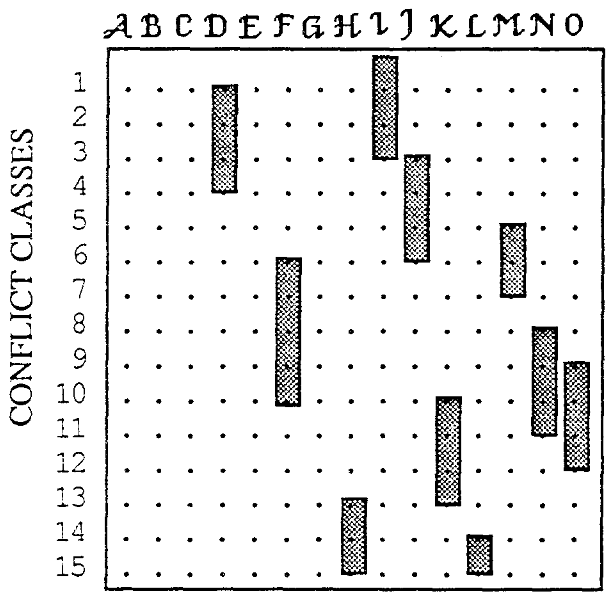
Table 6: Economic Problems Between the Countries

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
--	+A	+A	+E	+B	+A	+0	+A	+0	+0	+B	+A	+A	+A	+A	A
+0	--	+0	+D	+A	+A	+0	+A	+0	+0	+B	+A	+A	+A	+A	B
+0	+0	--	+D	+0	+0	+0	+0	+0	+0	+B	+A	+A	+A	+A	C
+A	+A	+A	--	+A	+C	+A	+B	+B	+B	+B	+A	+A	+B	+A	D
+A	+0	+0	+B	--	+C	+0	+0	+0	+0	+B	+B	+A	+A	+A	E
+A	+0	+0	+E	+A	--	+B	+B	+B	+0	+B	+B	+B	+A	+A	F
+0	+0	+0	+D	+0	+D	--	+B	+0	+0	+B	+B	+A	+0	+0	G
+0	+0	+0	+C	+0	+C	+0	--	+C	+C	+C	+B	+B	+A	+0	H
+0	+0	+0	+B	+0	+B	+0	+A	--	+0	+C	+C	+C	+0	+0	I
+0	+0	+0	+C	+0	+B	+0	+0	+0	--	+C	+A	+A	+0	+0	J
+0	+0	+0	+C	+0	+C	+0	+B	+A	+0	--	+C	+C	+C	+C	K
+0	+0	+0	+B	+0	+C	+0	+0	+B	+B	+C	--	+C	+D	+B	L
+0	+0	+0	+C	+0	+B	+0	+B	+0	+0	+B	+C	--	+C	+C	M
+0	+0	+0	+C	+0	+B	+0	+0	+0	+0	+C	+C	+C	--	+C	N
+0	+0	+0	+B	+0	+0	+0	+0	+0	+0	+C	+C	+C	+C	--	O

Table 7: Reduced Economic Problems Between the Countries

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
A	--	+A	+A	+D	+A	+A	+0	+A	+0	+0	+A	+A	+A	+A	+A
B	+0	--	+0	+C	+A	+A	+0	+A	+0	+0	+A	+A	+A	+A	+A
C	+0	+0	--	+C	+0	+0	+0	+0	+0	+0	+A	+A	+A	+A	+A
D	+A	+A	+A	--	+A	+C	+A	+B	+B	+B	+A	+A	+A	+B	+A
E	+A	+0	+0	+A	--	+B	+0	+0	+0	+0	+A	+A	+A	+A	+A
F	+A	+0	+0	+C	+A	--	+A	+A	+A	+0	+A	+A	+A	+A	+A
G	+0	+0	+0	+C	+0	+C	--	+A	+0	+0	+A	+A	+A	+0	+0
H	+0	+0	+0	+B	+0	+B	+0	--	+B	+C	+B	+A	+B	+A	+0
I	+0	+0	+0	+B	+0	+B	+0	+A	--	+0	+B	+B	+C	+0	+0
J	+0	+0	+0	+C	+0	+B	+0	+0	+0	--	+B	+A	+A	+0	+0
K	+0	+0	+0	+B	+0	+B	+0	+B	+A	+0	--	+B	+B	+B	+B
L	+0	+0	+0	+B	+0	+B	+0	+0	+B	+B	+B	--	+B	+C	+B
M	+0	+0	+0	+B	+0	+B	+0	+B	+0	+0	+B	+B	--	+B	+B
N	+0	+0	+0	+C	+0	+B	+0	+0	+0	+0	+B	+B	+B	--	+B
O	+0	+0	+0	+B	+0	+0	+0	+0	+0	+0	+B	+B	+B	+B	--

Table 8: Reduced External Conflict Potentials for 1996



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APPENDIX 1 to

ANNEX IV

SUBSIM SIMULATION EXPERIMENTS ON STABLE DEFENCE

Contents

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CHAPTER 1

SUBSIM -- SMALL UNIT BATTLE SIMULATION MODEL

1. SUBSIM is a critical event, automatic decision Monte Carlo game implemented on a VAX 8650. The program is written in FORTRAN 77. SUBSIM is developed by the Danish Defence Research Establishment.

2. SUBSIM has a rather detailed terrain description based on a 50 metre grid with terrain obstacles superimposed. The terrain model is used for line of sight calculations, and for the computation of presented target area. In most Danish terrain the 50 metre grid size will be entirely adequate. The game area is limited to 3 by 6 kilometres, which is sufficient for a battalion sized attack force against a company sized defence force. The 6 kilometre length of the game area, however, will only give limited space for the study of retrograde defence operations.

3. The visual, the near infrared, and the far infrared detection mode have been implemented. They are based on the single glimpse detection probabilities with a constant time between consecutive fixations of the observer's eye (or the night vision equipment). Each unit may have up to 3 different observers sharing between them the sector of responsibility allocated to that unit. Flash occurring when a weapon is fired may attract the attention of an observer for a certain amount of time, causing the observer to search in the direction of the flash with an accuracy that decreases with time. Also the influence of smoke is considered. On one hand the smoke will influence the detection process by decreasing the meteorological visibility, or in the case of FLIR by increasing the background temperature. On the other hand, a smoke cloud used by a unit for self-concealment may attract the attention of an observer and cause him to look in the direction of the smoke screen for a single glimpse. The smoke attraction effect continues for a certain time. Handing over of targets from one unit to another is also possible, using the flash attraction model for this purpose.

4. Each attacking unit will follow a fixed route, defined by up to 15 corners given by their terrain co-ordinates, and with a velocity specified for each route leg. The attacker may stop at each corner, unless it has been decided that it will move forward to the last corner without stopping, or that it may stop only at corners giving cover. Attacking units being exposed to hostile fire may seek for cover at a point outside the fixed route, unless a game parameter is set to prevent such an incidence. If cover is permitted, and a cover point is found closer than the next corner, a cover route is automatically generated. After being released from the cover point the cover route will take the unit back on the normal route.

5. The updating of the unit positions is taking place with a fixed time interval. It is possible to locate units at times between the fixed time events. All decisions concerning the movement of the attacking units according to a number of tactical rules are defined by appropriate game parameters.

6. Each of the defending units will have a number of defence positions available for shift of position. The new position may be chosen at random, excluding the last or the last two positions held. This option will normally be used when the defence task is to hold a given defence line. In the case of retrograde defence operation the defence positions are chosen consecutively, leading the defence back to a new defence line. Automatic transition from line defence to retrograde movement is possible.

7. Decision rules describe the change of defence positions according to certain tactical rules set up by appropriate choice of a number of game parameters. When a shift of position is decided, the new position is selected, and a route between the two positions is automatically generated, passing through the waiting positions connected with each of the defence positions.

8. The inter-visibility is examined with great accuracy. The area of a target that can be seen above terrain from a given position is calculated.

9. Engagement conditions are also examined at fixed time intervals, and decision to engage is made either autonomous or by integrated fire control. Any type of direct firing weapon may be simulated, be it missile or gun. For each missile round fired the impact point is determined with great accuracy, and the result is deducted in terms of a kill, a hit without kill or a miss. Three kill states are included, the mobility or M-kill, the fire power or F-kill, and the catastrophic or K-kill. Besides, the program regards the suppressive effect of a near miss, introducing it in terms of a threat or T-kill. By the suppression the unit is prevented in performing its normal line of action for a given period of time, function of the proximity of the near miss.

10. Also indirect firing is included in the game. Both sides may call for artillery support, either in the form of HE shelling, or in the form of smoke screening or blinding. Artillery may be automatically released as a function of a number of decision criteria. For HE shells each impact is examined with regard to its effect on targets present. Observation of own effect may improve the accuracy of second round point of impact, both for direct and indirect fire.

11. For direct fire a shoot-look-shoot mode may be applied, or a specified number of rounds may be fired in fast sequence against the same target. A number of decision criteria may be used individually to manage the tactical behaviour of the units with regard to

such items as fire on the move, fire from cover only, stop on the route for firing, turning the vehicle before firing, reloading with same or a specified ammunition type and for tanks the application of range finding equipment and lead angle computers.

12. Attacking units may generate smoke for self-concealment when exposed to hostile firing. Thus they may interrupt line of sight before missile impact if missile firing has been observed.

13. Once started, the game will continue until one side or the other falls to meet one of a number of precisely defined criteria, or until a maximum game time has elapsed. Thus it is possible to generate a series of replicas of the same battle situations. A statistical program is used for the extraction of information from a series of games.

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CHAPTER 2

ACTIVE SEMI-STATIC DECOYS

2.1 SCENARIO

14. The scenario used for the SUBSIM simulation experiments is essential equal to the scenario used by AC 243 (CCD) in a study on "The effectiveness of decoys in their use in tactical deception."

15. The base case is a battalion sized attack force against a company sized defence force. The battle takes place in a relatively flat area situated in the northern part of Germany. The attack consists of 18 attacking APCs (with AT-3 missiles) advancing towards a defence line and of 9 tanks (T64-B), which are tasked to give supporting fire to the attacking APCs. The defence consists of 9 tanks (LEOPARD 1 A5).

16. The defending tanks fight from prepared positions. After having detected an enemy unit a tank will move from a turret down position till the hull down position. The tank will carry out one engagement in the hull down position and then return to the turret down position. This engagement cycle will continue during the whole period of combat. The supporting tanks of the attacker will remain in their hull down positions during the move of the APCs. In these positions the tanks will only expose the turret to enemy fire.

17. The (tank) decoys are in hull down positions similar to real units. The shape of a decoy is identical to the shape of a real unit. The decoy is active producing similar flash and smoke trails as the fire of the real units. The only job of the decoy is to attract enemy fire and thereby reducing the number of engagements on the real units. As seen from an enemy unit there is no difference in signature and behaviour between real units and decoys. In addition to the ability to produce a signature similar to real units the decoys are assumed to be semi-static, i.e. the decoys have a pop-up/pop-down ability at a specific terrain position where they have to stay during the battle.

18. The simulation will stop if the moving attacking units reach their objectives or if the defender or the attacker suffers more than 60% losses.

19. Two measures of effectiveness (MOE) have been applied. The first MOE is the relative exchange ratio produced as the proportion of attacker losses divided by the proportion of defender losses. A value greater than 1 indicates that an unaltered continuation

of the battle will result in annihilation of the attacker before the defender. The second MOE is the percentage of simulation experiments leading to a defence victory. The values of the MOEs are calculated on the basis of 50 replicas of the individual experiment.

20. To evaluate the effect of tank decoys the base case was modified by replacing three tanks with six tank decoys. This leads to a situation in which each of the tanks operates in conjunction with a decoy. When a defending tank moves into the hull down position the corresponding decoy becomes exposed. It starts producing flash and smoke trails as the real unit and it remains exposed for a time corresponding to a normal engagement time. The decoys of the attacker are exposed like the attacking tanks and stay in their hull down position.

2.2 RESULTS

21. Three variations on the base case were conducted. In the first variation both the defender and the attacker replace 3 tanks with 6 decoys. In the second variation only the defender replaces tanks with decoys, and in the third variation only the attacker performs the replacement.

Attacker Defender	9 Tanks, 18 APCs	6 Tanks, 18 APCs and 6 Decoys
9 Tanks	1.02 56%	0.62 26%
6 Tanks and 6 Decoys	1.39 78%	1.15 50%

Measures of Effectiveness: Relative Exchange Ratio (Defender-to-Attacker)
Percentage D

Table 1.1 Simulation experiments with decoys.

22. The obtained results from the simulation experiments are given in table 1.1. If both the defender and the attacker use decoys the obtained result is not significantly different from the base case. However if either the defender or the attacker use decoys the party will gain significantly compared to the base case. Other simulation experiments have been conducted with variation over the number of tanks and the tactics used. In all situation the results obtained were similar to the results in table 1.1.

23. The scenario has deliberately been chosen with the purpose that it should be possible for the defender and as well as the attacker to make use of decoys. In the scenario, it is possible for the defending units and for the attacker's direct fire support units to move into

their positions without being observed by the enemy units. Normally, a defence from prepared position has the capability the make an effective use of decoys. The time is sufficient for preparing positions for the decoys in order for these to operate similar to real units. The decoys can be in positions before the enemy units start the attack. On the contrary, it is not always possible for the attacker to employ decoys effectively. The decoys can only be used in conjunction with supporting direct fire units. If these units have to move exposed to their positions it would be difficult to plan positions for decoys and it would be difficult to place the decoys in the positions without being observed and recognised. Therefore the defender should choose the terrain to make it difficult if not impossible for the attacker to use decoys.

2.3 OBSERVATIONS WITH RESPECT TO STABILITY

24. The use of decoys increases the military capability of the defending and attacking units. The decoys are semi-static with a pop-up/pop-down ability and can produce flash and smoke trails like a real unit. The simulation experiments show that the defender and the attacker may gain approximately equally if both parties may use decoys. The ability to deploy decoys effectively may however be different for the defender and the attacker. A defence from prepared positions will provide the possibility of preparing the insertion of decoys in a way that the resemblance to real units is adequate. Only in few cases it would be possible for the attacking unit to deploy decoys unexplored by defending units. Therefore, it is expected that the defence will be able to employ decoys effectively in more cases than the attack.

25. The great advantage of employing decoys and the greater possibilities for the defence to do so clearly indicates that employment of decoys will enhance stability.

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APPENDIX 2 to

ANNEX IV

JANUS MODEL AND EXPERIMENTS

Contents

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CHAPTER 1

JANUS EXPERIMENTS

1.1 HYPOTHESIS

1. The Janus experiments were designed to test hypothesis 4.2.3.2.a: that infantry is stabilizing because it cannot successfully assault a defended position. If this hypothesis were true, we would expect to observe increasing attacker casualties as less armor-heavy forces are introduced on both sides. Moreover, the hypothesis implies that it should be impossible to construct a successful attack with pure infantry forces. To test this hypothesis thus requires a series of experiments with variance in the infantry content of the attacking and defending forces, and including at least one "pure" infantry attack force. The hypothesis would be undermined if a successful attack could be constructed using a pure infantry force against a similarly armed opponent under conditions normally thought unfavorable for offensive infantry operations.

2. For these experiments, we assumed that the "purest" realistic infantry force would be one consisting of foot soldiers transported by wheeled, unarmored vehicles. Although the "purest" theoretical infantry force might be one consisting solely of walking foot soldiers, the ubiquitous availability of motor transport in modern economies makes this a highly unlikely form of military organization -- even if a combatant adopted such an organization in peacetime, its forces could readily be equipped with civilian transport in time of war.

1.2 COMBAT SCENARIO

3. To test the hypothesis, the following combat situation was developed: As part of a wider, theater-level defense, a United States-style mechanized brigade was assigned to defend across a relatively flat, open river plain, approximately 20 kilometers wide. With the bulk of force situated on the left side of the river, the right flank (to the right of the river) was defended by a battalion task force, composed of two mechanized companies and a company of tanks. Their primary mission was to prevent attacks along two major roads running parallel to the river. Reinforcing these units were six anti-tank missile vehicles, deployed on a plateau rising above the plain, with clear lines of sight across the battalion's sector. Across the river, and in support, were an additional nine anti-tank missile vehicles, again with clear lines of sight across the battalion's sector.

4. Opposing the defending brigade was a former Soviet-style motorized rifle division, whose mission was to establish an initial breakthrough in the defending brigade's sector. To carry out this task, one motorized rifle regiment was placed on the left bank of the river, to act as a covering force, while the remaining motorized rifle and tank regiments attacked along the river's right bank. The latter motorized rifle regiment's mission, attacking in echeloned battalion formation, was to roll up the defending battalion's right flank for a follow-on attack and breakthrough by the tank regiment. Only the initial portion of this attack plan was actually simulated for the Janus experiments: that is, the motorized rifle regiment's attack against the defending battalion task force.

5. Prior to the motorized rifle regiment's attack, scouts were sent out to probe the defender's lines. Intelligence received from these reconnaissance missions indicated the location of the defender's front line and the general deployment of forces along it. The presence of the anti-armor force on the left bank of the river was noted as was the prominent plateu in the center of and just behind the defender's front--an excellent observation point. Based upon this information, artillery missions employing smoke were planned along the river, around and atop the plateu, along the right side of the defender's front to cover the attacker's initial advance, and along four gaps in the defender's lines timed to coincide with the attack's progress as it rolled up the defender's flank. The attack was preceded by a 25 minute artillery barrage.

1.3 EXPERIMENTAL DESIGN

6. The scenario described above constituted the base case for the experiments. The order of battle for the base case is shown in Table 1. In this case, the attacker did not dismount his infantry from their infantry fighting vehicles, choosing instead to maximize assault velocity.

7. Three excursions involved progressively lighter (that is, more infantry-heavy), forces on both sides. In the first excursion (labeled the "IFV Case" in Table 1), all tanks were replaced with infantry fighting vehicles. In the second excursion (the "APC Case" in Table 1), all tanks and infantry fighting vehicles were replaced with lighter, armored personnel carriers. In the final excursion (the "Truck Case" in Table 1), all tanks, infantry fighting vehicles, or armored personnel carriers were replaced with five-ton transport trucks. In each excursion, the anti-armor vehicles were identical to the vehicles transporting the infantry (e.g., in the truck case, the anti-armor vehicle was a five-ton truck equipped with a

TOW missile launcher). Moreover, in each excursion, the attacker's infantry dismounted for the assault. As the forces became lighter, the attacker's artillery preparation became heavier: the 25-minute artillery preparation preceding the attack in the base case was increased one hour in the IFV case, two hours in the APC case, and three hours in the truck case.[1] The attack was considered complete when the defending unit on the defender's far left flank had suffered 70 percent attrition.

TABLE ONE
ORDER OF BATTLE

Base Case	IFV Case	APC Case	Truck Case
Defender	Defender	Defender	Defender
15 BMP-TOW's	15 BMP-TOW's	15 BTR-TOW's	15 Truck-TOW's
13 T-72's	33 BMP-2's	33 BTR-70's	33 Trucks
20 BMP-2's	231 Riflemen	231 Riflemen	231 Riflemen
140 Riflemen	33 Anti-tank Teams	33 Anti-tank Teams	33 Anti-tank Teams
20 Anti-tank Teams	1 Artillery Battery	1 Artillery Battery	1 Artillery Battery
1 Artillery Battery			
48 AFVE's	48 AFVE's	48 AFVE's	48 AFVE's
Attacker	Attacker	Attacker	Attacker
15 BMP-TOWs	15 BMP-TOWs	15 BTR-TOWs	15 Truck-TOWs
40 T-72's	130 BMP-2's	130 BTR-70's	130 Trucks
90 BMP's	910 Riflemen	910 Riflemen	910 Riflemen
630 Riflemen	130 Anti-tank Teams	130 Anti-tank Teams	130 Anti-tank Teams
90 Anti-tank Teams	1 Artillery Battalion	1 Artillery Battalion	1 Artillery Battalion
1 Artillery Battalion			
145 AFVE's	145 AFVE's	145 AFVE's	145 AFVE's

[1] Any intelligent military commander would employ different tactics as his force mix changes to best exploit the available combat systems and weapons. The defender's forces were arrayed differently across the four cases, to take best advantage of the particular weapons mix in each case. So too, the attacker slowed his attack tempo as his forces lost their armor protection. For more on these issues, see Stephen D. Biddle, *The Determinants of Offensiveness and Defensiveness in Conventional Land Warfare*, Ph.D. Dissertation, Harvard University, 1992

8. In all four cases examined, the defender's forces were deployed to provide the best lines of sight and fields of fire possible. Moreover, the defender's vehicles were dug in to hull defilade, while dismounted infantry were deployed in fully prepared foxholes, exposing themselves only to fire their weapons. To further complicate the attacker's assault, and to make a more challenging test of the hypothesis, the assault took place in daylight, during clear weather, and was launched across an open, flat river valley, with little or no vegetation available for cover. Finally, the Janus model itself has certain limitations when modeling infantry that tend to bias results against a successful infantry attack (see section 2.8 below).

9. To control for extraneous variables, both attacker and defender were equipped with Soviet-style vehicles and US-style weapons (shown in Table 2). The structural capabilities of the vehicles were considered when arming them. For example, while the anti-armor BTR vehicle in the APC case mounted both a TOW missile launcher and a .50-caliber machinegun, the anti-armor truck was equipped only with the TOW missile laucher. Infantry fighting vehicles, armored personnel carriers, and trucks were all provided with identical eight-man infantry squads. All vehicles and infantry were provided with identical optical sensors.

TABLE 2
WEAPON SYSTEMS

Combat System	Weapons
T-72	120mm main gun (HEAT and AP rounds) and .50-caliber machinegun
BMP-2's	25mm Bushmaster gun and Improved TOW missile
BTR-70's	.50-caliber machinegun
Truck	.50-caliber machinegun
BMP-TOW	Improved TOW missile and .50-caliber machinegun
BTR-TOW	Improved TOW missile and .50-caliber machinegun
Truck-TOW	Improved TOW missile
Anti-tank Teams	TOW missile
Riflemen	M-16 rifle
Artillery	152mm SP Howitzer

10. An Armored Fighting Vehicle Equivalent (AFVE) was used as a unit of measurement for comparing the two forces. An AFVE was defined to be any complete vehicle including its weapons suite and (for infantry-carrying vehicles) its passengers.[2] In other words, a tank constituted one AFVE as did an infantry fighting vehicle plus its eight-member infantry squad (an infantry fighting vehicle alone, as well as each infantryman, thus accounted for one-ninth of an AFVE). The initial force ratio (attacker versus defender) in all four cases was three to one. To obtain sufficient statistics at the 95 percent confidence level, twenty-four runs were made of the base case, eight for the APC case, and ten each for the IFV and truck cases.

1.4 RESULTS

11. The simulation results from these four cases (shown in Table Three and Figures One and Two) do suggest that infantry forces can successfully attack a defended position. The percentage of the attacker's losses when APC's or trucks were employed were not greater than his losses in the more armor-heavy base case. As both attacker and defender lightened their forces, and moved more towards a "pure" infantry situation, the attacker's ability to carry out a successful assault did not diminish.

TABLE THREE
JANUS SIMULATION RESULTS*

	Defender's Average AFVE Losses	Attacker's Average AFVE Losses	Defender's Mean Fractional Losses	Attacker's Mean Fractional Losses	Average Assault Time (hours)
Base Case	32.7 ± .5	98.7 ± 4.9	.84 ± .01	.68 ± .03	1.5
IFV Case	38.1 ± .7	119.5 ± 4.1	.98 ± .02	.82 ± .03	4.5
APC Case	37.6 ± .6	82.2 ± 2.3	.96 ± .01	.57 ± .02	5.0
Truck Case	38.4 ± .2	76.2 ± 3.5	.98 ± .01	.53 ± .02	6.1

* Intervals shown are for a 95 percent confidence level based on the *t* distribution.

[2] The AFVE measurement used here is simply an accounting device, it is not meant to be a measure of relative firepower or capabilities across different combat systems.

FIGURE ONE

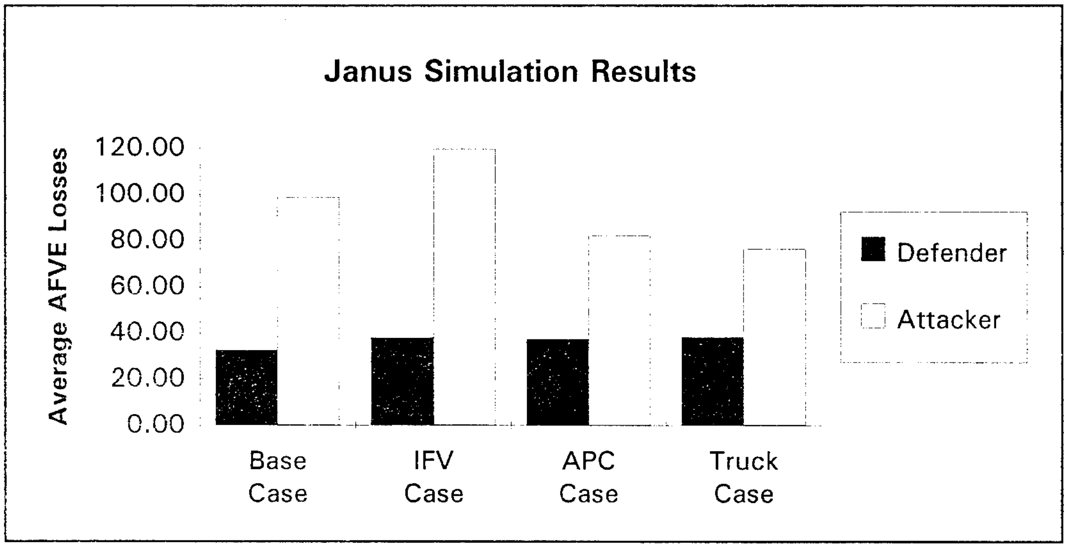
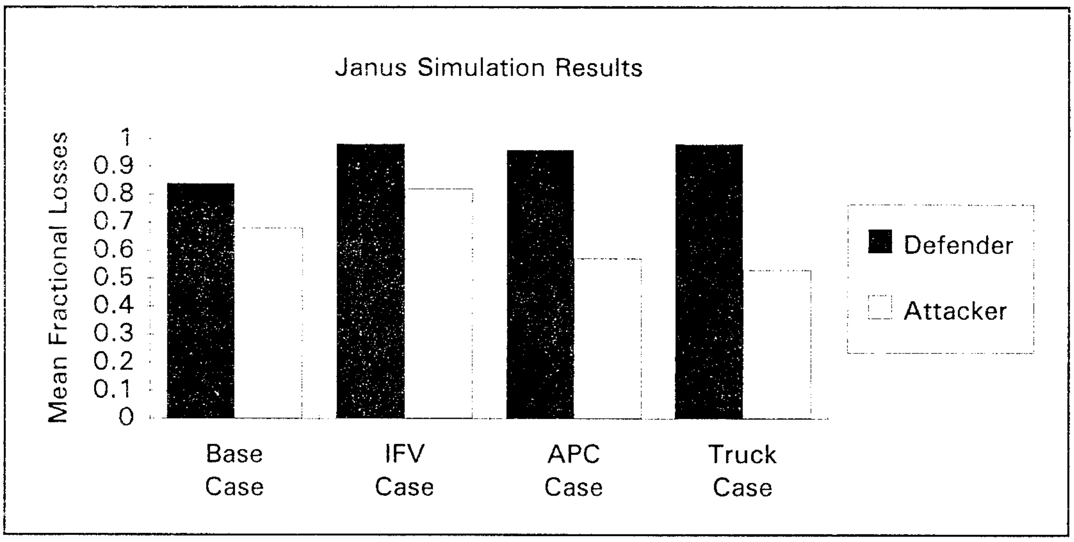


FIGURE TWO

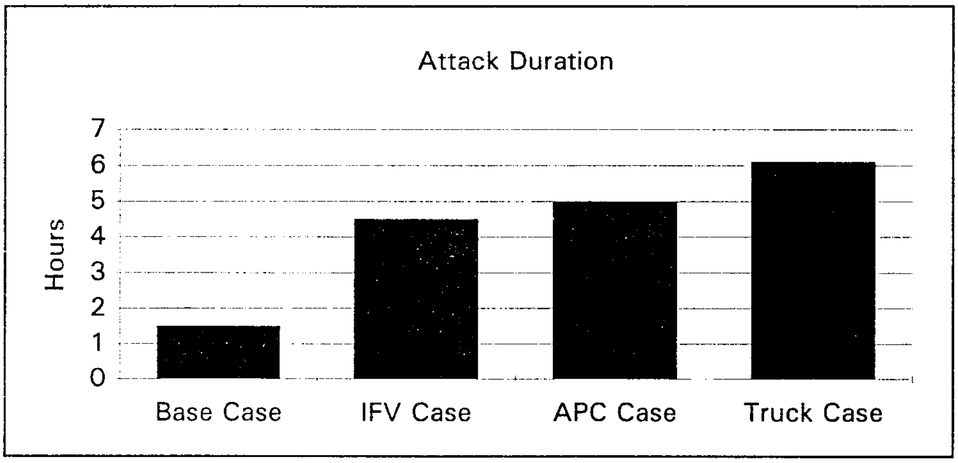


12. The attacker, however, did have to slow down the tempo of his attack as the forces became less armor-heavy, with a four-and-half hour increase in the time required to complete the attack in the truck case versus the base case (see Table Four and Figure Three). While there is no evidence that such a delay would be decisive for the success of the theater attack as a whole, the effect of such a velocity reduction warrants further analysis.

TABLE FOUR
ATTACK DURATION

	Hours
Base Case	1.5
IFV Case	4.5
APC Case	5.0
Truck Case	6.1

FIGURE THREE



13. Overall, though, the results obtained tend to disconfirm the hypothesis--and to do so strongly, given the highly infantry-unfavorable nature of the terrain and weather conditions assumed here.

1.5 LIMITATIONS

14. As is the case with most analyses, there are some problems with the results. For instance, it is not clear that the base case attack is a definite success. Possible degeneracy in the base case is far from an ideal situation. Had time allowed, we would have liked to strengthen this attack to ensure its clear success, perhaps by dismounting the infantry from

their infantry fighting vehicles.[3] The IFV case results are a bit more anamolous, but appear to stem largely from the very low lethality of a Bushmaster gun against a BMP in hull down positions (a factor of two or more reduction in the probability of kill given a hit from the case where BMP targets are exposed). Although care has been taken to check many of the parameters, time did not allow a complete review of all the input data. In exploring novel combat situations in Janus one occasionally runs into shooter-target pairs rarely encountered in the past.[4] While Janus data is generally quite good and well documented, these novel situations bring to light areas of the database of uncertain validity. Nonetheless, this single instance fails to overthrow the study's general results.

[3] Such a tactic also would have reduced the difference in attack duration between the base case and the truck case.

[4] In the spirit of the Cold War, most previous Janus scenarios saw the TOW-equipped vehicle on the defensive against an exposed, attacking BMP. The low lethality of the Bushmaster against hull defilade vehicles may also help to account for the attacker's high losses in the base case.

CHAPTER 2

JANUS COMBAT SIMULATION[5]

2.1 GENERAL DESCRIPTION

15. Janus is a two-sided, highly disaggregated, interactive, division/brigade level model useful for exploring relationships between weapon systems, combat, and tactics. It uses an event sequenced computer simulation to model stochastically at a fine grain of detail many of the interactions between individual combat systems in or near real time. Players, representing commanders, provide the strategy and tactics used by the two sides, either interactively or on a preplanned basis. Users have a great deal of flexibility in determining the capabilities of individual combat systems, and in choosing force employments and weapons mixes.

16. There are a number of different versions of Janus, all with the same basic structure. For these experiments we used the Janus-L version, developed by Lawrence Livermore National Laboratory's Conflict Simulation Laboratory starting in 1978. The Janus family of models has been used throughout the U.S. military, especially in the U.S. Army, as well as in several other NATO member countries, as both an analytical tool and a training simulation.

17. The simulation program is written in FORTRAN, and runs on any of the VAX family of Digital Equipment Corporation computers. Simulation graphics can be displayed on up to 24 Tektronix graphics workstations with one or two players per workstation, allowing the two sides' forces to be divided among the workstations, for example, by organization (maneuver battalion 1, maneuver battalion 2, etc.) or function (maneuver, logistics, artillery support, etc.). The simulation software is unclassified, as is the database used in the RSG experiments.

---

[5] This section is based upon Dianne R. Calloway, Scott D. Elko, John J. Rhodes, Jeffrey E. Pimper, Michael J. Uzelac, and Joe Wilson, *The Janus Simulation Guide, Version 4.05*, *The Janus Utilities Guide, Version 4.05*, and *The Janus Algorithms Guide, Version 4.05* (Lawrence Livermore National Laboratory, 1 February 1990)

18. In Janus, each single item (tank, BMP, infantryman, etc.) is defined to be a combat system. Janus models these combat systems, the interactions between them, and their interactions with the battlefield environment (including terrain, obstacles, and some weather phenomena) at the individual combat system level. One or more homogeneous combat systems (e.g., all M-1's or all BMP-2's) can, in turn, be combined into a unit. Up to fifteen combat systems can be aggregated to form a unit, with the number of systems per unit set by the user. Movement planning, target acquisition, and graphics are all performed using the unit as the basic entity. Each system within a unit, however, has its own unique position relative to the unit's center of mass and its own ammunition supply. Moreover, each system chooses its own enemy targets for direct fire engagement. Kills, again, are assessed at the individual system level. The data--which are stored in scenario, PK and terrain files--can be interactively reviewed and rapidly changed by the user through menu driven editing utilities.

19. A wide variety of combat system characteristics can be modified using the Janus scenario editor. These characteristics include descriptions of the weapons carried by each system and the capabilities of these weapons (wire-guided, laser-guided, self-guided, or ballistic; shell speed; rounds per trigger pull; etc.). Movement speeds and the effects of terrain on movement are specified for each system. Initial ammunition and fuel loads are described, as is the rate of fuel consumption and various supply/resupply performance data. Crew performance is represented by a number of data, including weapon response and reload times. The sensor types (naked eye, binoculars, optical video, IR, etc.) and capabilities are also described for each sensor mounted on a combat system. Finally, the model represents nuclear and chemical weapons effects.

20. Probability of hit (PH) and probability of kill (PK) tables for each weapon versus each potential target can be edited using the PK editor. These tables are used to determine lethality over range, status of the shooter, and orientation/status of the target for each shooter-target pair. A specific Janus PK file can contain up to 999 PH/PK data sets drawn from a master database containing up to 9,999 PH/PK sets.

21. The probability of hit curves are stored as a set of 16 curves, indexed by a PH set number, for each target-shooter pair. The 16 curves in each set are a binary function of shooter movement status (moving or stationary), target movement status (moving or stationary), target defilade status (in defilade or exposed), and target orientation relative to the incoming round (head-on or flank). Each curve in the set is a function of range, with six range values specified by the user. The PH values between the specified ranges are linearly interpolated.

22. The probability of kill given a hit curves are also stored as a set of 16 curves, indexed by a PK set number, for each target-shooter pair. In the current version of Janus-L (5.13), however, only four of these curves are used by the model. Specifically, the

model only considers "mobility or firepower" kills; the other three kill categories ("mobility" kill, "firepower" kill, and "catastrophic" kill) have yet to be implemented. The four curves used by Janus in each set are a binary function of target defilade status (in defilade or exposed) and target orientation (head-on or flank). Like the PH curve sets, each curve in the PK set is a function of range, with six user-specified range values, and values between those given linearly interpolated.

23. A terrain editor allows input and modification of terrain surface features such as vegetation, buildings, roads, and rivers. These data are stored as an array of cells on a three dimensional terrain grid of up to 400 x 400 data cells, allowing, for example, a 40 kilometer square to be displayed on a grid of 100-meter cells. Information about the area represented by each cell, such as tree or building density or the presence or absence of roads, is contained in the cell. The cell also contains the elevation at the location represented by its lower left corner. Elevations between these data points are linearly interpolated. Map displays are standard UTM maps, using digitized data from the United States' Defense Mapping Agency, land satellite data, and other sources.

2.2 JANUS FUNCTIONAL AREAS

24. The data provided by the user is employed by the Janus simulation to model the physics behind a wide variety of tactical and combat functions. Among the functional areas modeled are:

25. Target Acquisition -- For IR and optical sensors, the user is provided a choice of two sensor models: the ASARS acquisition model as modified for the Star Model by the Naval Postgraduate School, or the Night Vision Electro-Optical Laboratory (NVEOL) acquisition model as modified by the US Army's Training and Analysis Command at White Sands Missile Range (TRAC-WSMR).

26. Direct Fire Engagement -- Janus models weapon and ammunition effects, crew performance, and logistic constraints. Target choice is affected by range, probable lethality, and user designated priorities of fire. Individual system engagement is automatically determined by the computer, provided the shooter-target pair meet certain criteria.

27. Indirect Fire Engagement -- The model allows interactive planning of multiple firing missions, which can be sequenced as immediate or timed. The number of volleys for each mission also can be designated. Preplanned fire missions may be combined with preplanned movement orders. Specific artillery units may be designated to function in a direct support role, responding automatically to fire missions requested from forward observers. High explosive, improved conventional munition, smoke (Hexachloride or White

Phosphorus), chemical, and nuclear (with up to five user-specified yields) munitions are modeled.

28. Defilade -- The ability of a unit to position itself in relationship to the enemy such that it is afforded some degree of protection from observation and engagement by intervening terrain is called defilade. A unit in Janus may be exposed, in partial (hull) defilade, or in full (turret) defilade. The defilade state may be manually controlled, or it may be allowed to function independently (a 'popup' unit). For popup units, input data specify how long it takes a system to move from full defilade to partial, set up to shoot, and return to full defilade.

29. Movement -- Janus allows interactive planning of movement routes, including player defined implementing times. A unit's speed is calculated based on its movement capability, slope of the terrain, on or off road status, engagement status, and building/tree densities. The player may designate a ground unit to move at "rate" or "fast" speed, and variable flight speeds and heights are available for aircraft. Movement orders are planned as check points (or nodes) toward which units move. Check points may be identified with a time ("time" nodes) to allow preplanned halts such as in a phased attack.

30. Mount/Dismount -- Systems may be given a capability to carry other systems, with specified constraints on how much can be carried (by weight and volume), and the required time to mount or dismount the items. The player may interactively mount and dismount systems during the course of the game.

31. Engineer Capabilities -- Janus models obstacles such as rivers, minefields, ditches, craters, and abatis. The user determines the capabilities of individual units to clear these obstacles.

32. Logistics -- Both direct and indirect fire ammunition use, as well as fuel consumed, are accounted for by the simulation for each unit. Supply depots and mobile units may be used to resupply depleted units interactively during the game, with the amounts of fuel and ammunition transferred accounted for.

33. Status Reports -- Detailed information on the status of units and forces is available in a selection of on-screen printed reports which may be requested as needed during a simulation.

2.3 JANUS PROCESSES

34. The Janus simulation models the functional areas described above through a series of event-driven and time-stepped processes. A general description of the major combat-related processes follows:

35. Movement (event-driven) -- Dependent on the environment and on a unit's combat status, this process updates each unit's UTM grid coordinates when the unit is moving.

36. Direct Firing Engagement(event-driven) -- Upon acquisition of an enemy unit, a unit will shoot at the enemy if the enemy is within the range fan of the shooter, sufficient ammunition is present, and the unit is in a "shoot" state. At the time of firing two events are scheduled: the arrival of the shot fired, dependent on shell velocity and distance; and the time of the next firing, dependent on the system's reload rate.

37. Direct_Fire_Assessment (event-driven) -- Upon arrival of a shell at a target a stochastic assessment is made based on the lethality of the weapon (based on PH and PK curves) which is dependent on the range of the engagement, the status of the shooter, and the status/orientation of the target.

38. Indirect_Fire_Assessment (event-driven) -- The area effects of high-explosive, improved conventional munitions, smoke, nuclear and chemical munitions are assessed at the time of impact of the shell. A stochastic assessment is made of units within the radii of effects of the shell, based on the shell's characteristics as well the capabilities of its artillery piece. For high explosive shells, the user can choose between a cookie-cutter style algorithm or the "Carlton" algorithm to assess effects.

39. Acquisition (time-stepped) -- Once line-of-sight is established between units, the cumulative probability of acquisition is computed based on sensor type and capabilities, at fixed time steps specified by the user until acquisition occurs.

40. Line-of-Sight (time-stepped) -- The status of the line-of-sight between units of opposing sides are updated at a fixed time interval specified by the user.

41. Interactive_Planning (interrupt) -- Human "commanders" use interactive graphics devices (graph tablets) to input maneuver and artillery mission firing orders to units assigned to the commander. When the planning process is active, the model polls the interactive workstation between modeled events to update the interactive graphics.

42. Three of the most important sets of processes for the purposes of the RSG experiments were movement, target acquisition and direct fire. Each are described in more detail below:

2.4 MOVEMENT PROCESS

43. Players can give movement routes to any of their units either during the initial planning phase of the game or interactively while the game is running in response to changes in the tactical situation. Movement routes take the form of a set of check points or nodes. A stationary unit will remain stationary if it has no orders to move. Additionally, a unit will remain stationary at a "stop" or "time" node. If the unit is given a movement order, is released from a "stop" node, or a "timed" node expires, the unit will begin movement in a straight line towards its next check point.

44. A unit's movement is slowed, delayed, or stopped by a variety of factors; for instance, if the system characteristics require the unit to stop or slow down when firing its weapon system. A unit's movement also is delayed when traveling cross country, with the speed of movement determined by the slope of the terrain, the system's movement characteristics, and the density of vegetation. If an engineer obstacle intersects the path of a ground unit, the unit will halt. If the unit can, it will then clear the obstacle with a certain time delay. Movement continues when the obstacle is cleared. A unit will halt once its final check point is reached.

2.5 TARGET ACQUISITION PROCESSES

45. Target acquisition is composed of two processes: line-of-sight and target acquisition. Line-of sight (LOS) between units is calculated from the heights of the units above ground at their current grid locations. In order to determine whether line-of-sight exists between any two units, the terrain elevations (plus unit height) at each unit's grid locations and at several points between them are calculated. Line-of-sight is broken by intervening terrain or by smoke. Buildings and trees will also block LOS; a unit, however, may be able to see out of a city or tree grid. Line-of-sight calculations are initiated whenever one unit penetrates or is within the region around an enemy unit that defines its limit of visibility range.

46. The visual target acquisition process, the process of locating and identifying enemy units, begins only once line-of-sight has been established between the observer and the target. The target acquisition process is performed for each observer unit against every enemy target unit within its line-of-sight. Even if LOS exists, acquisition will not occur if the distance between the observer and the target is greater than the ambient visibility or if the target is outside the observer's assigned field of view.

47. Provided that the distance is less than or equal to the ambient visibility and that the target is within the observer's field of view, then the target acquisition process continues. If the observer has not previously been trying to acquire the target, the cumulative

probability of acquisition is initialized to 0.0, the duration clock is set to 0.0, and a random threshold probability is generated using a uniform distribution. For subsequent attempts, the time since the observer's last attempt to acquire the target is added to the duration clock. The delta increase in probability to acquire is calculated, based upon either the ASARS or the NVEOL model (selected by the user) and the characteristics of the sensor in use by the system. This delta increase is added to the cumulative probability. If the cumulative probability meets or exceeds the threshold probability, then acquisition occurs and the target unit is added to the observer's list of enemy units acquired. The target unit is then displayed upon the observer player's screen. If the threshold condition is not met before a set time has elapsed, the acquisition process is reinitialized and begins again after an additional time interval has passed. The process continues as long as the observer has line-of-sight to the target. If at any time during the acquisition process the line-of-sight is broken, the acquisition process is terminated. How often each unit is checked for line-of-sight and target acquisition is a parameter entered by the user before the game begins.

2.6 DIRECT FIRE PROCESSES

48. Direct fire consists of two processes: direct fire target engagement and direct fire effects assessment. If a unit has targets on its acquisition list, and if its meets certain status criteria (e.g., that it is alive, that it is a shooter, that it is in the "shoot" mode, etc.), then it begins the direct fire target engagement process. Each system in a unit chooses its own target to engage. Once a target is chosen, the system will continue to engage the target until the target or system is killed, until line-of-sight between the system and target is broken, until the system's parent unit is placed in the "no shoot" mode or into full defilade by its owning player, or until the system's parent unit is mounted on another unit from which he is prohibited from shooting. The system will find a new target to shoot at if, after it fires at a target, it determines that there is another system in its unit that is also engaging the target. If the system fires a self-guided or sensor-guided missile at a target, it will not fire another missile at the same target until the first one has impacted. It may, however, engage other targets while the missile is in flight.

49. Once a system has selected a target, there is a delay, called the "response time", before it engages the target. The mean value for the response time is an input parameter (each weapon type has its own mean response time). The actual response time is generated by making a random draw from the normal distribution with the input value as the mean and standard deviation equal to 20 per cent of the mean.

50. After the first shot, each subsequent shot at the same target is fired after another delay, called the "reload time." The mean value for the reload time is also an input parameter (each weapon type has its own mean reload time). The actual reload time is again

generated by making a random draw from the normal distribution with the input value as the mean, but with standard deviation now equal to 10 per cent of the mean.

51. Both response time and reload time may increase if the system's parent unit has suffered degradation due to nuclear, chemical, or other degrading effects.

52. Once a round is fired, determination of whether the target is killed is undertaken by the direct fire effects assessment process. The probability of kill is computed by multiplying the probability of obtaining a hit on the target (PH) by the probability of killing the target given a hit (PK). The probabilities are determined from the curves created by the PK editor with data provided by the user. The values chosen depend on the range of the engagement, the status of the shooter, and the status/orientation of the target.

2.7 INTERACTIVE PLAY

53. During the course of a Janus game, the model allows the player to perform interactively a number of functions. The player can give his units movement orders and plan indirect fire missions. He can designate which units he wants to be forward observers and which artillery units he wants in direct support roles. He can place stationary units in full or partial defilade, place appropriate units in pop-up status, and prevent some units from firing their weapons ("no shoot" mode). He can resupply combat systems with fuel and ammunition, activate certain engineer obstacles (abatis and craters), and mount or dismount units from other units (e.g., mount or dismount infantry from armor personnel carriers or helicopters). The player can also request a host of on-screen reports describing the status of individual units or combat systems, as well as the state of his overall force. A command-and-control (CAC) capability allows the player to create graphic overlays on his screen and to send these and other messages to other workstations on his side.

2.8 MODEL LIMITATIONS

54. Like any model, Janus does not represent every combat relationship perfectly nor does it include every variable relevant to combat, all of which introduces some element of bias. For example, soldiers always have "perfect" courage, morale, and stamina; weapons never jam; and equipment never wears out. Moreover, inherent limitations in Janus leave out factors especially relevant to infantry. With 100-meter square terrain cells, it is impossible to represent the small undulations and folds in the ground used by infantry for cover, especially by infantry in the attack. The same limitation prevents modeling infantry infiltrating through defensive lines. These limitations, however, tend to bias results in a

conservative fashion relevant to the hypothesis tested for the RSG. In other words, they tend to take away opportunities that infantry normally possess when attacking defended positions.[6]

[6] For more on modeling infantry in Janus, see Stephen D. Biddle, ibid.

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APPENDIX 3 to

ANNEX IV

KOSMOS SIMULATION EXPERIMENTS ON STABLE DEFENSE

Contents

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CHAPTER 1

ON THE SCOPE OF THE EXPERIMENTS

1. As a contribution to the RSG.18 study on Stable Defense, about 17,000 simulation experiments have been performed with the battle simulation model KOSMOS over a period of two years. They covered 340 different scenarios featuring attacks by two different types of generic divisions, one tank-heavy and the other infantry-heavy, against three different types of defending brigades, one tank-heavy, one infantry-heavy and one intermediate, of different strength each and under different situational conditions involving three types of terrain, two visibility conditions and up to three degrees of defense preparation.

2. This is the most comprehensive series of simulation experiments ever organized by the Institute for Applied Systems and Operations Research (IASFOR) of the Federal Armed Forces University Munich on one study topic. Thus, in addition to addressing the primary question raised by the RSG.18, it offered a unique opportunity for testing the rather complex model in the light of results, leading to a continuous improvement that can be observed when comparing the results of the four series of experiments undertaken within the two year period. For example, the sometimes non-monotonous behaviour of results that was observed during the initial two series of experiments had largely disappeared in the last two series. This is attributed primarily to improvements of the command and control models, or rather of the rule sets controlling tactical and operational decisions in the KOSMOS simulations. These improvements reduced the effects of structural variance that is always present, but frequently not noted, in two-sided battle simulation models of some complexity.

3. These observations confirm the conviction shared at IASFOR that the development of battle simulation models must be accompanied by extensive testing, and that the development of tactical and operational rules or expert systems, be it for the purpose of controlling simulations or life operations, need to be done iteratively by reviewing rules in the light of the success or failure of the operations controlled by them. To this end, "automated" procedures for the assessment of the outcome of battle simulation experiments are indispensable.

4. The need for the development of an automated evaluation procedure was recognized rather early in the study. Otherwise, it would have been impossible to cope with the mass of experiments that were required for addressing at least some of the stability hypotheses forwarded by RSG.18. Thus, as a byproduct so to speak, an evaluation system was developed that tries to capture, in form of a scalar "simulation value", the essential criteria for the assessment of the success of a local attack, i.e., a break-through in a main-thrust sector.

5. There are two primary objectives for the simulation experiments performed at IASFOR, namely

a. to provide quasi-empirical information for the validation or falsification of the stability hypotheses developed by RSG.18;

b. to test the two fundamental assumptions underlying the Stable Regional Force Ratio (SRFR)-concept, proposed by IASFOR for the assessment of multipolar military stability, on the availability of

   - adequate scoring systems for estimating the defensive and offensive combat power of given force postures in form of scalar values;

   - distribution functions for the probability of an attacker breaking through a defense in a main-thrust sector over the initial attacker:defender combat power ratio there.

6. The stability hypotheses for which information is provided by the experiments are related to

- closure rates in an attack
- terrain
- force-to-force ratios
- force-to-space ratios
- cover and concealment
- tanks
- infantry
- artillery
- short range SSM
- mechanization of land forces
- motorization of land forces.

7. Both of the fundamental assumptions of the SRFR-concept seem justified, at least when considering scenarios similar to those of the experiments. In particular, the scores of the British Balance Analysis Modelling System (BAMS) in combination with the situational multipliers of RAND's Situational Force Scoring System (SFSS) provide measures for computing combat power ratios in main-thrust sectors that are very close to those computed on the basis of weapon system weights obtained from the simulation experiments involving mechanized defenders and armoured attackers.

8. The simulation results prove that there are situation-dependent monotonous relationships between the probability of break-through and the initial local force-to-force ratio.

9. However, many more simulation experiments on a greatly extended set of generic tactical scenarios are required for generating a data base that would be sufficient for applying the SRFR-concept to the analysis of multipolar stability problems in the real world.

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CHAPTER 2

CHARACTERISTICS AND ARCHITECTURE OF THE BATTLE SIMULATION MODEL KOSMOS

10. The battle simulation model KOSMOS[1] has been under development at the Institute for Applied Systems and Operations Research (IASFOR) of the Federal Armed Forces University Munich since 1986. It is designed as a tool for experimental research on

- modelling requirements for combat analysis;
- stability properties of weapon and support systems, of tactical doctrine and command and control philosophies, and of unit and force structures under different environmental conditions;
- aggregation methods for generating input data for higher level (analytical) models.

11. The essential characteristics of the simulation model KOSMOS can be summarized as follows:

- closed simulation without man-in-the-loop (brigade level up to corps level);
- resolution of the C^2-process down to the battalion and company level respectively; representation of the attrition of individual weapon systems;
- event-driven simulation superimposed by time steps: the latter approach is used for the simulation of continuous processes (e.g., by means of Lanchester differential equations), while discrete events (such as attrition caused by, e.g., CAS) are represented by an event-oriented simulation;
- deterministic and/or stochastic version for attrition, movement and C^3I: a fast-running deterministic version for testing the sensitivity, of the option under study, to a large number of scenario parameter constellations, thus providing information for the assessment of the option's robustness with regard

[1] KOSMOS: Korps-Simulationsmodell mit regelbasierter Steuerung (Translation: rule-driven Corps Simulation Model).

to uncertain scenario and control parameters;
a stochastic version with permits to establish, from a sufficient number of replications of simulation runs for a given scenario, probability distributions of the outcomes rather than merely expected values[2];

- detailed modelling of the C^3I processes (rule driven closed simulation) while retaining the option of interactive man/machine interface that offers the possibility of manual control for experimenting with "unconventional" decisions, and for developing the rule system in a trial-and-error fashion.

12. The simulation system KOSMOS is composed of three main parts: the input system, the simulator, and the evaluation system (see Fig. 2.1). They are connected by appropriate data interfaces (input system → simulator; simulator → evaluation system).

13. The *Input System* is to provide the following functions:

a. Assisting data input and change of rules underlying the C^2-process (ROSWITA);

b. graphical support for the development of operational plans (attack routes, defense positions, barriers, etc.);

c. testing of input data for formal correctness and plausibility;

d. transformation of input data describing the initial state of the system to be simulated (t=0), i.e., generation of the data interface between input system and simulator;

e. interpretation of the input data (partly in graphical form) for review by the experimenter.

14. The *Simulator* performs the experiments generating, for each simulation run, detailed protocols that document all events occurring during the simulation (interface simulator → evaluation system).

15. The *Evaluation System's* central element is a post-processor that permits to aggregate the protocol data in tabular and graphical form.

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[2] The significance of outcome distributions for the assessment of force structures and risk associated with given options due to random events on the battlefield and the C^3I-process has been shown in previous KOSMOS experiments.

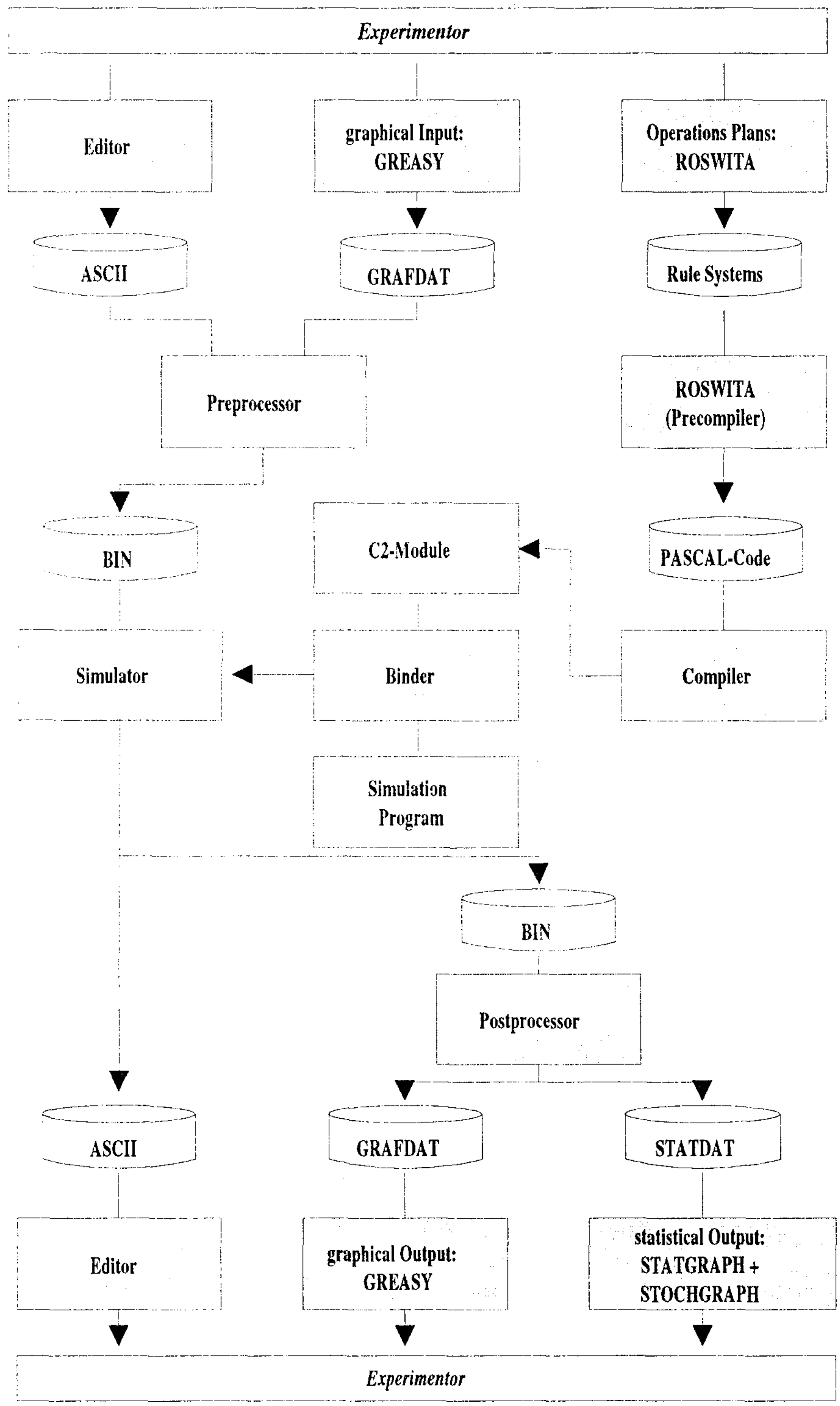

Figure 2.1: Functional Design of the Simulation System

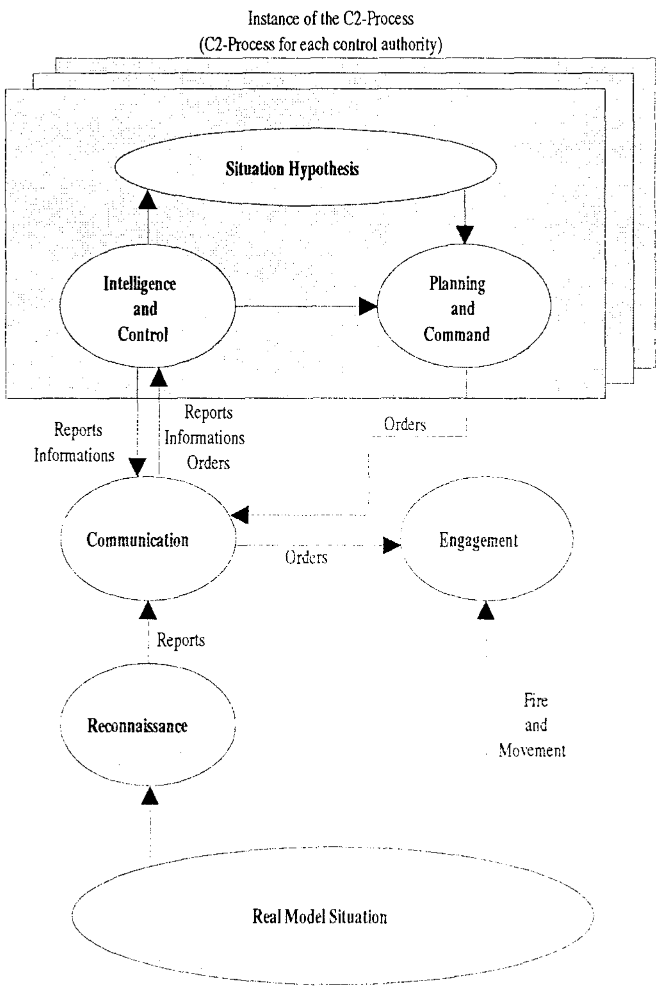

Figure 2.2: Basis Structure of a Rule Driven Closed Simulation System

16. The Simulator consists of four basic models (see Fig. 2.2):

a. The *Engagement Model* represents functional descriptions of attrition and movement of the simulation objects.

b. The *Reconnaissance Models* simulate the activities of the various sensor systems which provide the principal basis for the situation assessment in the C^2I-process.

c. The *Communication Model* describes the delays and/or interruptions in the transmissions of orders, reconnaissance messages, and situation indicators between the simulation objects (command authorities, recce means, manoeuvre units, etc.) caused by exogenous (enemy) and endogenous (reliability) events.

d. The *C^2I-Model* controls the engagement, reconnaissance, and communication models by means of rules.

2.1 ENGAGEMENT MODEL

17. The *Engagement Model* includes a series of sub models which describe, among other things, attrition and movement processes as they result from mutual operational plans, force interactions, battlefield geometry, terrain, terrain reinforcements, barriers, etc. Fig. 2.3 indicates the essential weapon effects relationships between opposed systems considered in the ground war part of KOSMOS.

18. Manoeuvre units (combat units at the manoeuvre level) usually represent battalions. They may be in either one of the following states:

- March;
- Attack;
- Prepared and Unprepared (hasty) Defense;
- Delaying Actions;
- Covered in Staging Area.

19. The time requirements for assuming a prepared defense state depend on the unit type. The model permits the units to be in several intermediate states (of partial preparation). For modelling of flank attacks and encirclement operations in a scenario independent manner, manoeuvre units are described in terms of appropriate geometric shapes in a rectangular grid terrain model.

20. By means of geometric procedures, the model determines

a. the opposed units in contact and the fraction of engaged forces (n:m allocation problem);

b. the type of attack (frontal, flank, rear) a unit is faced with;

c. to what degree the opposed units participate in the engagement (as a function of the unit state and the visibility and terrain conditions).

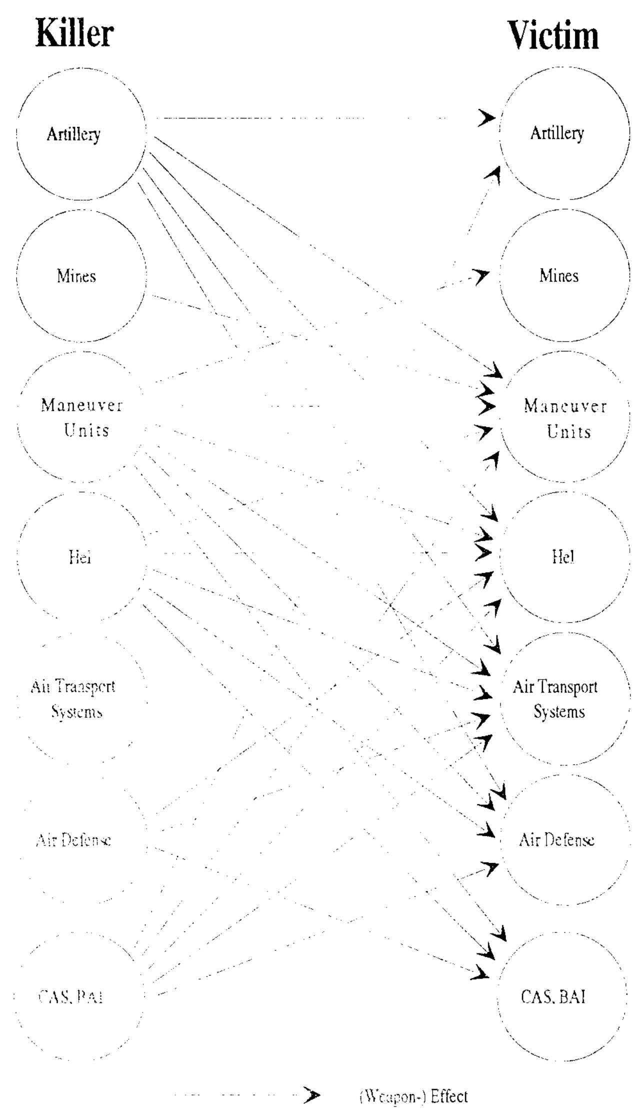

Figure 2.3: Air/Ground War Interactions

21. Only frontal forces may be employed for an attack. All other attacking forces are in a defensive posture, i.e., the attacker's flank and rear forces serve as security forces and become involved only if attacked there. The initial distribution of forces (along the sides of their geometric shapes, see Fig. 2.4) as well as the time required for regrouping, in case of being hit by attacks in the flanks and/or from the rear, are weapon system and unit-type dependent inputs. The fraction of forces participating in the engagements depends on the instantaneous distribution, and on the intersected area of the opposed geometric shapes.

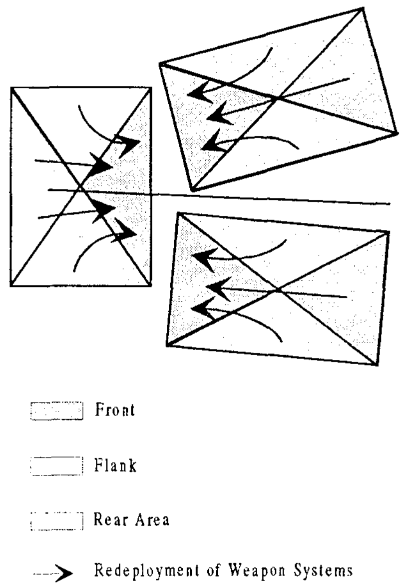

Figure 2.4: Schematic Representation of a Combat Manoeuvre Unit

22. The units move along polygons that reflect the operational plans and ad hoc orders generated by the C^2I-model. Reductions in the movement velocity along the legs of the polygons result primarily from losses suffered on the march or in contact with enemy forces as well as from encountered barriers.

23. The attrition caused by manoeuvre units and artillery is modelled by means of heterogeneous Lanchester equations (square law for direct fire attrition, linear law for indirect fire attrition). The attrition calculations are based on attrition rate coefficients, allocation factors, and the combat active fractions of the opposed forces as determined from the results of detailed simulations on the (tactical) item level.

24. Attrition caused by barriers/minefields, CAS/BAI, air defense and long range artillery systems imply discrete events which are modelled by special algorithms.

2.2 RECONNAISSANCE MODEL

25. There are two *Reconnaissance Models* implemented in KOSMOS, a *multi-sensor* and a *single-sensor* model.

26. The multi-sensor model explicitly considers the various sensor types and reconnaissance missions. Depending on the type and state of the employed sensors (see Fig. 2.5), the reconnaissance/sensor model generates by means of a (yet to be developed)

multi-sensor fusion model, at specified time steps, situation reports for the situation estimation in the command HQ's, and target reports for the fire support systems.

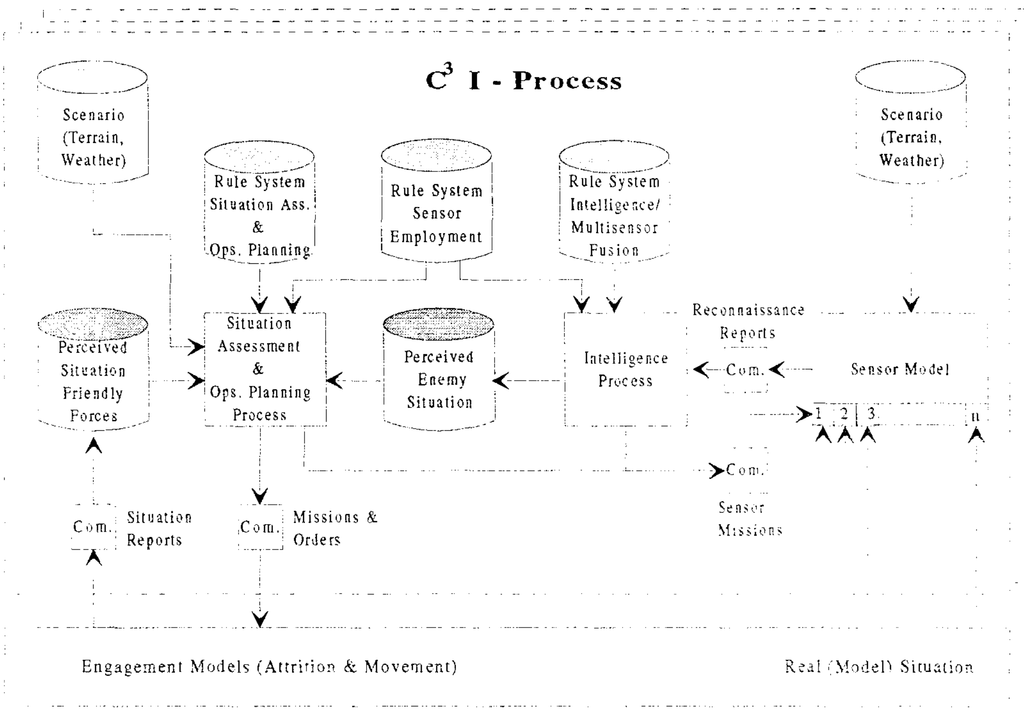

Figure 2.5: Basis Structure of the C3I-Process

27. The single-sensor model aggregates the different reconnaissance capabilities of a command and control authority in one generic sensor type. In this manner, the problem of multi-sensor fusion is avoided, thus greatly facilitating the highly sophisticated process of generating a perceived enemy situation for each command and control authority.

2.3 COMMUNICATION MODEL

28. The *Communication Model* assumes that - due to the redundancy of the communication system - transmission of a message is always accomplished, however, with delays of arbitrary duration. A communication link is not identical with a particular physical link such as a land line or radio transmitter-receiver. Rather, it is provided by the system of all available physical means of communication. The availability of a communication link is measured in terms of the average duration of the message transmission and its standard deviation. In addition, a communication link is not necessarily a point-to-point connection between two nodes, but more generally one between several nodes. Thus, all nodes along a line between a sending and receiving node may listen into the message transmission. Electronic countermeasures (ECM) lead to an increase in message transmission times between

all nodes located within range of the ECM source. The transmission time increase depends on the ECM intensity as well as the ECM susceptibility of the communication system.

2.4 THE C²I-MODEL

29. The *C²I-Model* (see Fig. 2.2 and 2.5) represents the general characteristics of the C²I-process on every command level. From the viewpoint of a systems analyst, all decision processes comprise three fundamental stages. In the first stage, the decision maker attempts to determine the context of the decision problem by analysing the decision environment (situation estimation/intelligence). In the second stage, he compares the perceived state of the environment to the desired stage that satisfies his or her objective functions, thus, defining the control requirements (control process). In the third stage, he applies an a priori defined set of (frequently heuristic) procedures in order to find an efficient strategy that leads from the perceived to the desired state (planning and command process).

30. The approach to model the military C²I-process is based on the idea of

- a rule-oriented representation of these three stages of a decision process[3] and
- their interconnection by means of a situation hypothesis which describes the decision context.

Thus, we have a generalized three-stage model of the C²I-process which is continuously specified, in the simulation, as a particular instance for each control authority. Each instance represents a particular C²I-model which describes the respective decision process and the applied decision rules as a function of parameters such as decision level or decision authority, type and state of controlled simulation object, situation hypothesis a.o.

31. The model of the intelligence process determines, for each command authority, the perceived situation which represents the respective commander's hypothesis about the actual enemy situation. It is established based on the reconnaissance efforts and the state of the reconnaissance and communication systems. Thus, the situation hypothesis is essentially an incomplete and, depending on the time delays in the communication system, a more or less up-to-date picture of the actual enemy situation. One's own situation is assumed to be known subject to the delays in the communication system.

[3] Rule-based approaches are especially suited for modelling decision processes under risk and uncertainty, features which are quite common in most battlefield decisions.

32. In order to support the situation estimation on all command levels, relevant reconnaissance information is always passed on - with the respective time delays - to the next higher and to neighbouring as well as all subordinate command authorities. In addition, the situation hypotheses of all co-operating command authorities are compared and aligned at given time intervals and/or when needed.

33. The model of the control process activates the planning and command process as soon as the respective command authority realizes that an operation does not proceed as planned, the situation has changed substantially, or when a super ordinate command authority has issued new orders. Thus, the control process is designed to activate the planning and command process only if needed.

34. The planning and command process represents the very heart of the C^2I-model. It is based on a rule system that basically implies the operational principles relevant in given scenarios. Based on the situation hypothesis, the model establishes the plan of operations and specifies the necessary orders to the subordinate units.

CHAPTER 3

DESIGN OF THE KOSMOS SIMULATION EXPERIMENTS

3.1 OBJECTIVES AND CLASSES OF SIMULATION EXPERIMENTS

35. One objective of the KOSMOS simulation experiments is to provide a generic data base for the assessment of offensive and defensive force capabilities and force balances by means of the aggregated analytical models proposed for the RSG.18 study. To this end, the experiments were to be performed not on military systems, units, and structures existing in or being planned for reality, but rather on classes of typical (generic) objects. However, in order to permit comparisons with the results of past and ongoing studies and analyses on "real" systems, the generic objects are to be defined in a manner that accommodates the respective systems.

36. In addition to satisfying the above mentioned objective, the simulation experiments should provide basic information for the definition of attributes or determinants by which offensive military forces may be distinguished from defensive ones. Furthermore, they should provide the basis for the comparative assessment of the various modelling approaches underlying the simulation models and the methods of data aggregation employed in the RSG.18 study, e.g., by means of scoring systems.

37. Given these objectives, two classes of simulation experiments may be distinguished:

a. Experiments for the investigation of attributes for distinguishing offensive from defensive elements (systems, units, structures);

b. Experiments on (local) breakthrough battles in main-thrust sectors permitting to define the threshold conditions under which breakthroughs must be expected in main-thrust sectors.

38. For each scenario, 50 stochastic replications[4] and one deterministic run were made. Amounting to a total of some 17,000 simulated battles. Each simulation

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[4] Stochastic models are used for the attrition process, the breakpoints of combat units and for some parts of the command and control and communication processes (communication time and situational perceptions of the commanders for the employment of tactical reserves and combat support units).

experiment was carried through between 10 to 20 hours of battle taking about 2 to 4 minutes computing time on a HP/APOLLO-workstation with 25 MIPS.

3.2 BASIC SCENARIO

39. Fig. 3.1 illustrates the basic scenario of a break-through battle. It features a division on both sides, each consisting of three brigades. In the base case, each brigade comprises four battalion size combat modules and three combat support modules (artillery batteries). Their generic equipment is described in chapter 3.3. The terrain in the basic scenario is assumed to be favourable to armoured/mechanized operations.

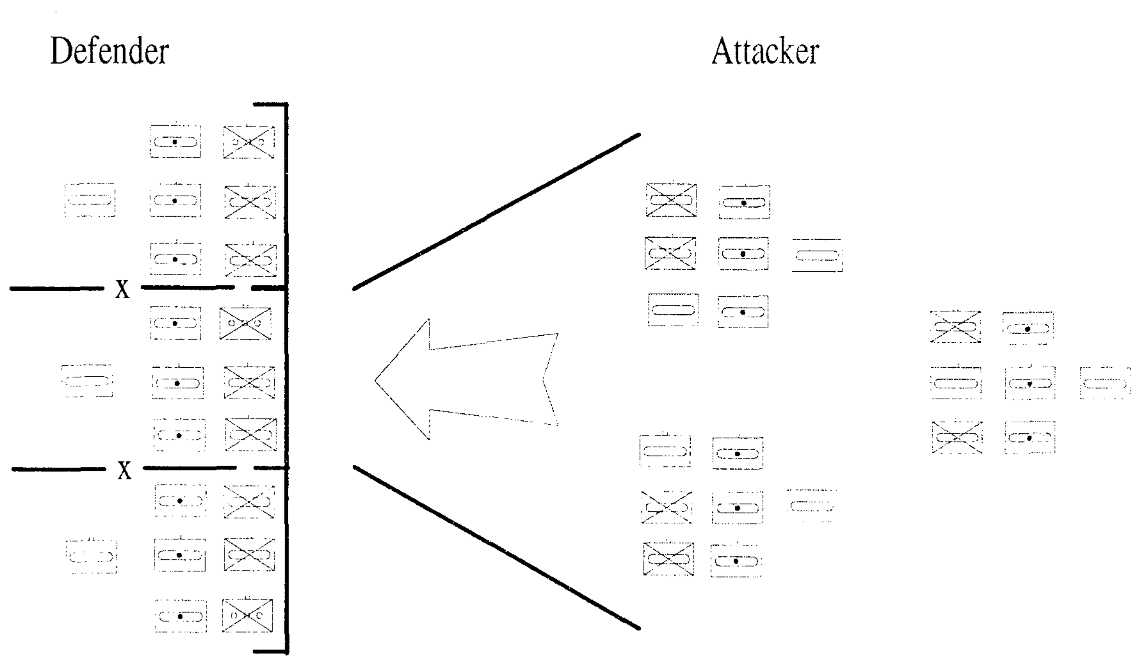


Figure 3.1: Schematic Representation of the Basic Scenario

40. The three brigades of the defending Blue side's division fight next to each other being assigned a sector of 15 km width each. Within the brigades, three (mechanized resp. motorized) infantry battalions are deployed to forward defense positions. Each brigade's reserve consists of one tank battalion. Its three artillery batteries are deployed behind the front battalions.

41. The division of the attacking Red side tries to break through the defense of the Blue brigade in the centre. The attack is organized into two echelons. The first echelon consists of two brigades attacking side by side, each with two mechanized infantry and one tank battalion in front and one tank battalion as reserve. In each brigade, the three artillery

batteries follow immediately behind the armoured infantry battalions. The second echelon consists of the division's third brigade, attacking along the same routes in a preplanned manner.

3.3 GENERIC WEAPON SYSTEMS, UNITS, AND STRUCTURES

3.3.1 General Unit Design Assumptions

42. Scenario variations are generated in a modular manner from generic objects. For the design of generic objects and scenarios, the following assumptions are made:

a. The generic unit level is the brigade which may be composed of different mixes of generic weapon systems contained in modules on battalion and company level. Being an independently operating (tactical level) unit, the generic brigade disposes of a minimal set of generic combat support systems depending on the brigade type configuration.

b. Large-scale units (divisions) are composed of different mixes of generic brigades and additional elements contained in a series of type-dependent combat and combat support modules (divisional troops).

c. Within the various categories of weapon systems, the number of generic types shall be kept as small as possible consistent with a sufficient differentiation concerning the criteria of armour, mobility, and firepower.

43. The basic ideas of this modular concept are the following:

a. A given generic scenario defines the initial conditions of a battle between attacker and defender. Both sides' forces consist of a supreme generic unit defined corresponding to the supreme control level.

b. Supreme generic units may be composed of

- large-scale generic units (division-level),
- generic units (brigade-level),
- combat modules (battalion-size), and
- combat support modules (company-size).

However, it must consist of at least one brigade-level generic unit.

c. The combat and combat support modules represent the smallest units from which the generic units are assembled. Modules may not be subdivided. They are composed of predefined mixes of generic weapon systems.

3.3.2 Generic Weapon Systems

44. Five classes of generic weapon systems are distinguished:

a. Direct Fire Weapon Systems,

b. Artillery Systems,

c. Helicopter Systems,

d. Air Defense Systems, and

e. Mine Systems.

45. Within each class, the following generic weapon systems are accommodated:

a. Direct Fire Weapon Systems

MMBT Modern Main Battle Tank with reactive/chobarm armour, thermal imaging, high mobility and high firepower (e.g., Leopard 2, XM-1, T 80);

AFV Armoured Fighting Vehicle with on-board weapons like machine guns and the capability to carry soldiers for mounted and dismounted combat (e.g., Marder, BMP);

ATRS Armoured Anti-Tank Rocket System installed on a vehicle characterized by high firepower, mobility, and long range. (e.g., BRDM-2, Jaguar);

MIT Mobile Infantry Combat Team (3 Soldiers) equipped with rifles, machine guns, anti-tank recoilless rifles and anti-tank rocket system (e.g., Milan or TOW 2)[5].

b. Artillery Systems

Mor Light Armoured Mortar; for supporting airborne troops or infantry (e.g., Field Howitzer D-30);

FHow Field Howitzer with conventional ammunition (e.g., FH155);

AHow Armoured Howitzer, highly mobile and less vulnerable than *FHow* (e.g., M 109, 2S1, 2S3);

RL (not armoured) highly mobile Rocket Launcher; employing HE-munition as well as bomblets and terminal guided munition (e.g., MLRS, BM-22);

c. Helicopter Systems

ATHel Anti-Tank Helicopter, mainly used in defensive operations, not armoured, cannot be employed over enemy area (e.g., PAH-1, OH-58D);

CHel Combat Helicopter, typical attack helicopter, partially armoured, may operate over enemy area (e.g., Cobra, HIND E);

d. Air Defense Systems

SRAD Short Range Air Defense System, mobile air defense artillery system escorting manoeuvre forces (e.g., 2S6, Gepard);

e. Mine Deploying Systems

MinEng Mine Systems deployed by Engineers equipped with mine laying systems (e.g., Scorpion);

---

[5] Their superior unit disposes of AFVs or APCs (e.g., M113) so that they may move under artillery fire. If they have AFV's at their disposal they can fight mounted and dismounted. Otherwise they fight dismounted. Furthermore, the MIT always uses the most suitable weapon.

MinArt Mine Systems deployed by Artillery (e.g., MLRS launching anti-tank mines);

3.3.3 Combat and Combat Support Modules

46. The combat and combat support modules represent the smallest grouping of weapon systems which are explicitly controlled by the C^3I process. They may not be subdivided. For the simulation experiments, six types of battalion-size combat modules and eight types of company-size combat support modules are defined (see Fig. 3.2):

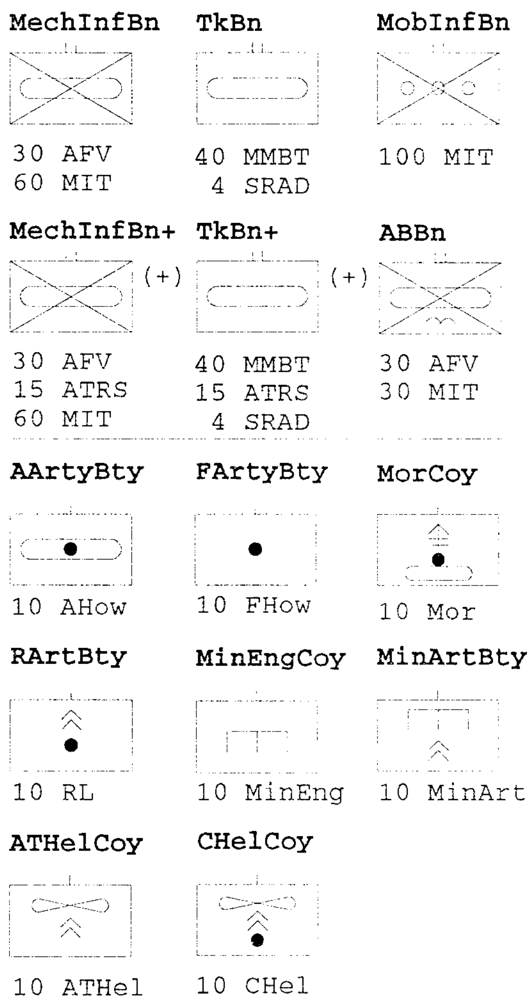


Figure 3.2: Combat and Combat Support Modules

a. Combat modules:

MechInfBn	Mechanized Infantry Battalion consisting of 30 AFV and 60 MIT. On the defending side, the MITs are supposed to fight dismounted and, given enough preparation time, in field fortifications. On the attacking side, this type of battalion follows the rules of the generic enemy forces catalogue of NATO, i.e., it fights mounted until reaching a preplaned dismounting line from where it tries to penetrate the defense positions in a dismounted mode;
MechInfBn+	Reinforced Mechanized Infantry Battalion, equipped with additional 15 ATRS, same doctrine as *MechInfBn*;
TkBn	Tank Battalion comprising 40 MMBT and 4 SRAD; this highly mobile module is often used as a tactical reserve on the defending side, and by the break-through forces on the attacking side;
TkBn+	Reinforced Tank Battalion equipped with 15 ATRS additionally;
MoInfBn	Mobile Infantry Battalion consisting of 100 MIT and equipped with APCs for mobility under fire. Despite the lack of AFVs, this generic object has remarkable defensive as well as offensive capability, especially under poor weather conditions and in rough terrain;
ABBn	Airborne Battalion consisting of 30 MIT and equipped like the *MechInfBn* (smaller type of AFV), same doctrine;

b. Combat support modules

AArtyBty	Armoured Artillery Battery with 10 AHow;
FArtyBty	Field Artillery Battery with 10 FHow;
MorCoy	Mortar Company with 10 Mor;
RArtBty	Rocket Artillery Battery with 10 RL;
ATHelCoy	Anti-Tank Helicopter Combat Group with 10 ATHel;
CHelCoy	Combat Helicopter Group with 10 CHel;

MinEngCoy Engineer Company with 10 MinEng;

MinArtBty Rocket Artillery Battery with 10 MinArt;

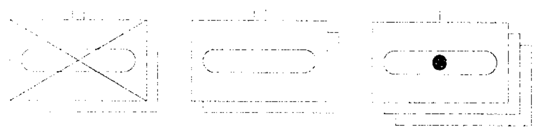
3.3.4 Generic Brigades and Divisions

47. Three types of MechInfBde's are distinguished: Type I is tank-oriented, Type II, infantry-oriented, and Type III is a mixed type with infantry teams and tanks used mostly as tactical reserves. So-called weak or minimum brigade types were defined for testing, under conditions of the basic scenario (see Fig. 3.1), the impact of combat support modules (chapter 5.1) and of force-to-force and force-to-space ratios (chapter 5.2). In contrast, reinforced brigade types were used in the experiments testing force structures and force-to-space ratios under different scenario conditions (chapter 5.3 and 5.4).

a. Weak (or minimum) brigade types:

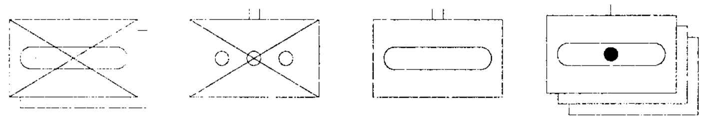
MechInfBde I (-) mechanized infantry brigade on the attacker's side, tank oriented, comprising two *MechInfBn*'s, two *TkBn*'s, and, as a minimal set of combat support, three *AArtBty*'s (see Fig. 3.3);

MechInfBde III (-) mechanized infantry brigade on the defender's side, mixed type, comprising two *MechInfBn*'s, one *MoInfBn*, one *TkBn*, and three *AArtyBty*'s (see Fig. 3.4).



MMBT	AFV	ATRS	MIT	SRAD	ATHEL	CHEL	AHOW	FHOW	MOR	RL	MINENG	MINART
80	60		120	8			30					

Figure 3.3: *MechInfBde I (-)*



MMBT	AFV	ATRS	MIT	SRAD	ATHEL	CHEL	AHOW	FHOW	MOR	RL	MINENG	MINART
40	60		220	4			30					

Figure 3.4: *MechInfBde III (-)*

b. Reinforced brigade types:

MechInfBde I (+) Tank-oriented Mechanized Infantry Brigade comprising one *MechInfBn+*, one *MechInfBn*, two *TkBn*'s, three *AArtyBty*'s, one *MinEngCoy* and, in addition (from the division), one *MoInfBn*, two *AArtyBty*'s, one *RArtBty*, one *MinArtBty*, and two *ATHelCoy*'s (see Fig. 3.5);

MechInfBde II (+) Infantry-oriented Mechanized Infantry Brigade, comprises three *MoInfBn*'s, one *ABBn*, two *FArtyBty*'s, two *MorCoy*'s, one *MinEngCoy* and, in addition (from the division), one *MoInfBn,* two *FArtyBty*'s, one *RArtBty*, one *MinArtBty*, and two *ATHelCoy*'s (see Fig. 3.6);

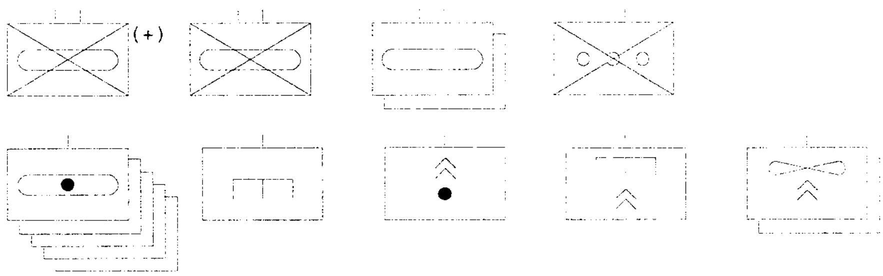
MechInfBde III (+) Mixed Mechanized Infantry Brigade, comprises two *MechInfBn*'s, one *MoInfBn*, one *TkBn*, three *AArtyBty*'s, one *MinEngCoy* and, in addition (from the division), one *MoInfBn*, two *AArtyBty*'s, one *RArtBty*, one *MinArtBty*, and two *ATHelCoy*'s (see Fig. 3.7);

b. Division types:

MechInfDiv Mechanized Infantry Division comprising two *MechInfBde III (+)* consisting of one *MechInfBn+*, one *MechInfBn*, two *TkBn*'s, three *AArtyBty*'s, and one *MinEngCoy*; one *MechInfBde II (+)* consisting of three *MoInfBn*'s, one *ABBn*, two *FArtyBty*'s, two *MorCoy*'s, and one *MinEngCoy*; in addition to these brigades, the division has two *MoInfBn*'s, two *AArtyBty*'s, two *FArtyBty*'s, two *MorCoy*'s, two *RArtBty*'s, three

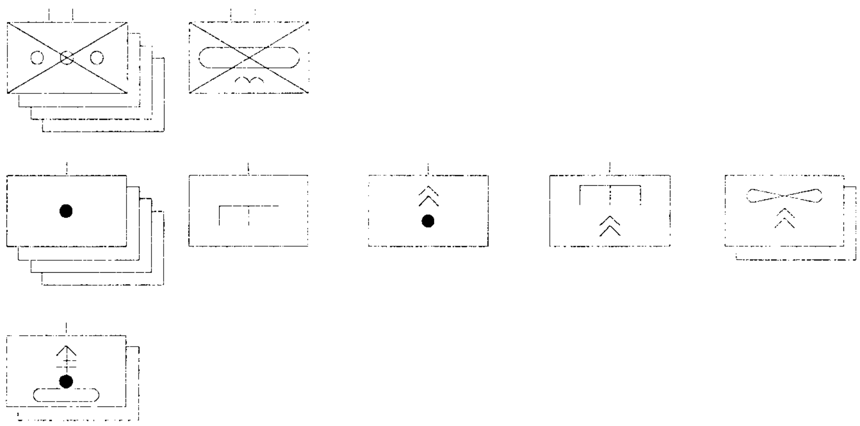
ATHelCoy's, one *CHelCoy*, two *MinEngCoy*'s, and two *MinArtBty*'s (see Fig. 3.8);

TkDiv Tank Division comprising two *TkBde*'s consisting of two *TkBn*'s, one *TkBn+*, three *AArtyBty*'s, and one *MinEngCoy*, one *MechInfBde I (+)* structured as described above; in addition to these brigades the division has two *MoInfBn*'s, four *AArtyBty*'s, four *RArtBty*'s, four *CHelCoy*'s, two *MinEngCoy*'s, and two *MinArtCoy*'s (see Fig. 3.9).



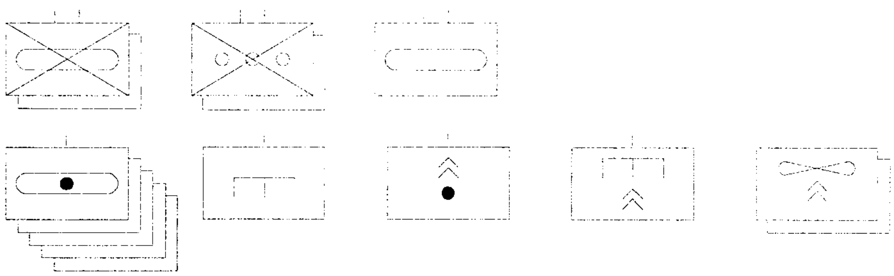
MMBT	AFV	ATRS	MIT	SRAD	ATHEL	CHEL	AHOW	FHOW	MOR	RL	MINENG	MINART
80	60	15	220	8	20		50			10	10	10

Figure 3.5: *MechInfBde I (+)*



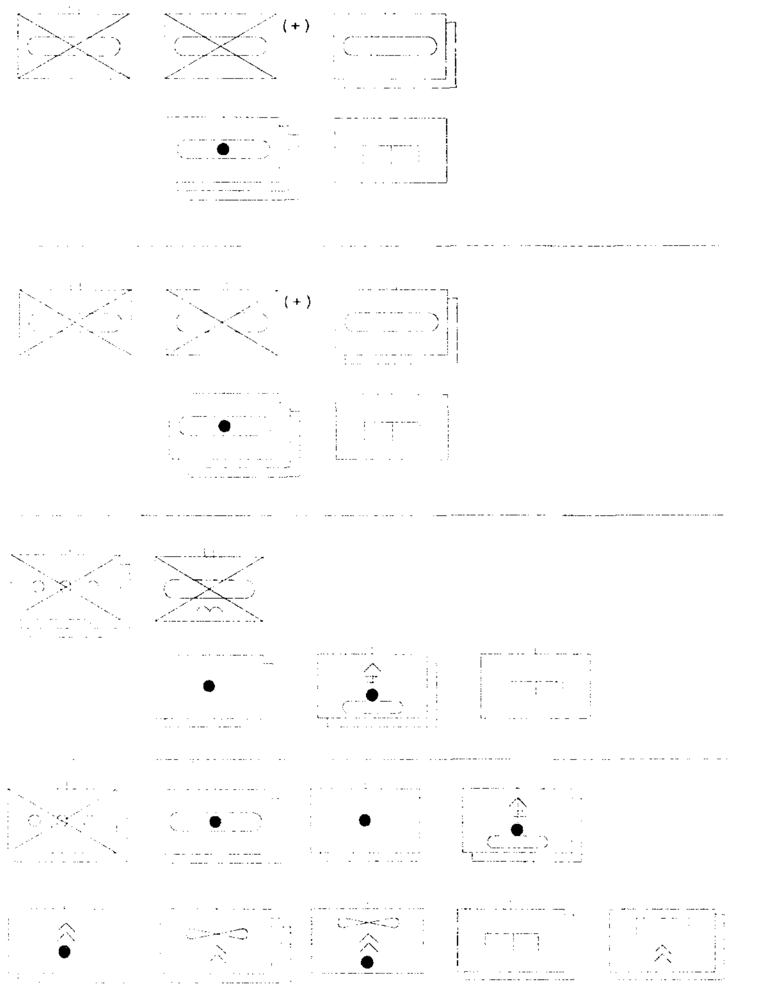
MMBT	AFV	ATRS	MIT	SRAD	ATHEL	CHEL	AHOW	FHOW	MOR	RL	MINENG	MINART
	30		430		20			40	20	10	10	10

Figure 3.6: *MechInfBde II (+)*



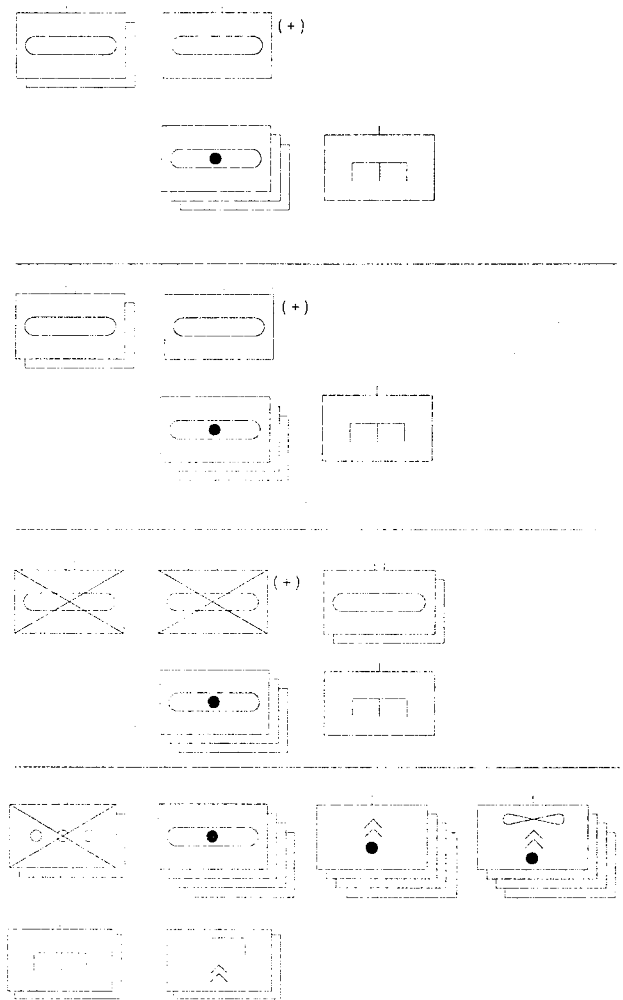
MMBT	AFV	ATRS	MIT	SRAD	ATHEL	CHEL	AHOW	FHOW	MOR	RL	MINENG	MINART
40	60		320	4	20		50			10	10	10

Figure 3.7: *MechInfBde III (+)*



MMBT	AFV	ATRS	MIT	SRAD	ATHEL	CHEL	AHOW	FHOW	MOR	RL	MINENG	MINART
160	150	30	770	16	30	10	80	40	40	20	50	20

Figure 3.8: *MechInfDiv*



MMBT	AFV	ATRS	MIT	SRAD	ATHEL	CHEL	AHOW	FHOW	MOR	RL	MINENG	MINART
320	60	45	320	32		40	130			40	50	20

Figure 3.9: *TkDiv*

3.4 RULE SETS FOR THE EMPLOYMENT OF COMBAT AND COMBAT SUPPORT UNITS

3.4.1 Combat of the Front-line Battalions

48. The Blue battalions in forward defense positions try to hold their sectors near the FEBA. (This is done in a static or mobile combat mode depending on their respective capability.) A defending combat battalion is neutralized when it reaches its breakpoint which is assumed to be at 40% of the initial strength (±10% deviation in case of stochastic simulations).

49. The attacking Red battalions try to break through the defense of the Blue brigade. A break-through occurs if an attacking Red battalion reaches the rearward edge of the Blue brigade's defense area at a loss level of less than 30% of its initial strength, regardless of whether the defending Blue battalion has reached its breakpoint or not.

50. An attack is aborted when the attacking Red battalion reaches its breakpoint which is assumed to be at 60% of the initial strength (±10% deviation in case of stochastic simulations). In that case, the surviving elements stop their movement and assume a defensive combat mode (unprepared).

3.4.2 Employment of Reserves

51. The rule system for the employment of the reserve battalions of the defending brigades[6] is based on the assumption that Blue has the order to hold the defense sectors near the FEBA and to prevent a Red break-through.

52. Thus the defending reserve battalions will be deployed

- to reinforce front-line forces if the local force ratio in a battalion defense sector reaches a critical point;
- to prevent Red combat units from penetrating deeply into the Blue brigade's defense area through a gap if one of the battalions at the FEBA reaches its breakpoint;
- to hold a Red combat unit that has penetrated deeply into the Blue brigade's defense area by occupying a defense position behind the FEBA;
- to counterattack a Red combat unit that has penetrated deeply into the Blue brigade's defense area.

---

[6] The employment of a brigade's tactical reserves is restricted to the respective brigade. For example, if the battalions of the brigades adjoining the sector of the engaged brigade in the centre become involved in combat, they may be reinforced from the reserves of their brigades only.

53. The attacking brigades will introduce their tactical reserves[7]

- in order to reinforce the success of a front-line battalion that has accomplished a break-through. In case more than one of the attacking battalions has been successful the reserve battalion is to deploy to the combat sector with the most favourable outcome;

- in order to maximize the chance for a break-through if none of the front line battalions is able to do so. In this case the tank battalion is deployed to the combat sector where the chance for a break-through is the highest.

54. If a reserve employment becomes necessary, the rule system chooses the most appropriate combat module if more than one reserve module is available.

3.4.3 Employment of Armoured or Field Artillery

55. The artillery batteries may be employed in order to

- deliver counter battery fire;

- fire into preplanned target areas (area fire);

- provide fire support for combat units (directed fire).

56. In order to maximize the effectiveness of the artillery fire, the employment of the artillery batteries of a brigade is coordinated under central control. The mode of employment and the target allocation of the artillery batteries are based on a generalized utility theory approach[8]. The rule sets are assumed to be the same for both sides. Each battery fires at its maximum rate.

57. Contrary to the employment rules for the tactical reserves, the artillery batteries of the Blue brigades on both flanks of the engaged brigade may provide fire support for the latter if the range of the artillery systems permits.

3.4.4 Employment of Rocket Artillery

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[7] The third brigade of the attacking division is used as the second echelon. It attacks along preplanned routes, i.e., it has an operation plan of its own.

[8] This generalised method reduces the problem of employment and target allocation to a $m \times n$-allocation problem based on a $m \times n$-utility-matrix with each value representing the expected utility, calculated using a specific utility function for the respective combat support weapon type. Using this $m \times n$-utility-matrix, the allocation is made in the sequence of the utility value taking into account the marginal utility.

58. The target allocation of the rocket artillery batteries depends on the highest expected utility calculated using a specific utility function adapted to the effectiveness and technical operating principles of the rocket artillery. The underlying rule system applies the above mentioned generalized utility theory approach.

59. Possible targets are

- enemy rocket artillery batteries being one of the main threats to one's own rocket artillery batteries;
- deployed enemy reserve battalions approaching their area of operation in the main-thrust sectors on both sides.

60. In addition the Blue rocket artillery batteries engage Red combat units that have penetrated deeply into the Blue brigade's defense area and are not engaged in direct combat.

3.4.5 Allocation of Close Air Support (CAS) and Battlefield Interdiction (BAI) Sorties

61. Aircraft are assumed to be a scarce resource allocated to support land force operations in the centre only. In the experiments, both sides employ 15 sorties (five missions with three a/c each) in preplanned missions against

- combat or artillery units in presumed positions without forward air controller (FAC).
- front-line combat units with FAC, and
- combat and/or artillery units on march.

3.4.6 Allocation of Helicopters

62. As a highly mobile fire support system, combat and anti-tank helicopters are assumed to be under central control of ground force commanders. They are to reinforce combat units in main-thrust sectors on both sides, on the Blue side when a break-through by Red is imminent or has occurred; on the Red side when the attacking ground forces are about to reach their breakpoints, or to exploit the success after a break-through has occurred. In order to optimize the allocation of the helicopters, a utility function similar to those described before is used. It should be pointed out that helicopters will be deployed only when the estimated combat power destroyed by them exceeds a given threshold (e.g., the estimated combat power loss resulting with helicopters kills).

3.4.7 Deployment of Minefields

63. In the simulation experiments, minefields deployed by *MinEng* as well as minefields deployed by *MinArt* are used to

a. delay Red combat units that have penetrated deeply into the Blue brigade's defense area and are not engaged in combat;

b. delay deployed enemy reserve battalions (Red or Blue) approaching their area of operation in the main thrust sector;

c. delay Red units approaching the FEBA;

d. guard the exposed flanks in a defense area in order to prevent Red units from attacking the flanks;

e. guard gaps resulting when battalions at the FEBA reach their breakpoints by delaying enemy forces attacking through these gaps, thus gaining time for countermeasures.

64. A defending brigade may use all of these options, an attacking brigade (or division) only option b. Decisions concerning the deployment of minefields are made using the above mentioned utility theory approach with a minefield-specific utility function.

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CHAPTER 4

GENERAL OBSERVATIONS ON RESULTS AND DEFINITION OF SUCCESS

4.1 DETERMINISTIC VS. STOCHASTIC RESULTS

65. Combat as well as command and control processes exhibit a degree of randomness that contributes significantly to the variance in the outcomes of fire fights and battles. Therefore, the information value obtained from the results of deterministic simulation models is limited at best. This is illustrated by Fig. 4.1 which depicts the evolution of the overall attacker:defender force ratio over time for each of the 50 replications of the battle fought under the conditions of the base case scenario. It will be noted that the mean or expected values obtained from fifty replications of the stochastic experiments differ considerably from the result of the deterministic model even though the deterministic models of the individual processes have been shown to be unbiased[9]. One of the reasons may be that the stochastic simulation results reflect the effects of the well known attack doctrine of *reinforcing success* according to which the attacker allocates his reserves to whichever sector where the battle happens to take the most favourable course. Thus, from the viewpoint of the defending party, deterministic model results must be considered being too optimistic. This effect is most prominent when the initial force ratio is at or near the so-called *break-even-force ratio* at which the odds are the same for both antagonists.

66. From the fact that the overall attacker:defender force ratio decreases in all cases, one cannot conclude that the battle outcomes are always favourable to the defender, or that no break-throughs occur. Whether this is the case or not is only revealed when looking at Fig. 4.2 showing the battle trajectories in the main-thrust sector, i.e., the defense sector of the centre brigade in the basic case scenario.

[9] Unbiased means that, the mean value obtained for a sufficient number of replications from the stochastic model of a process converges to the value resulting from the deterministic model.

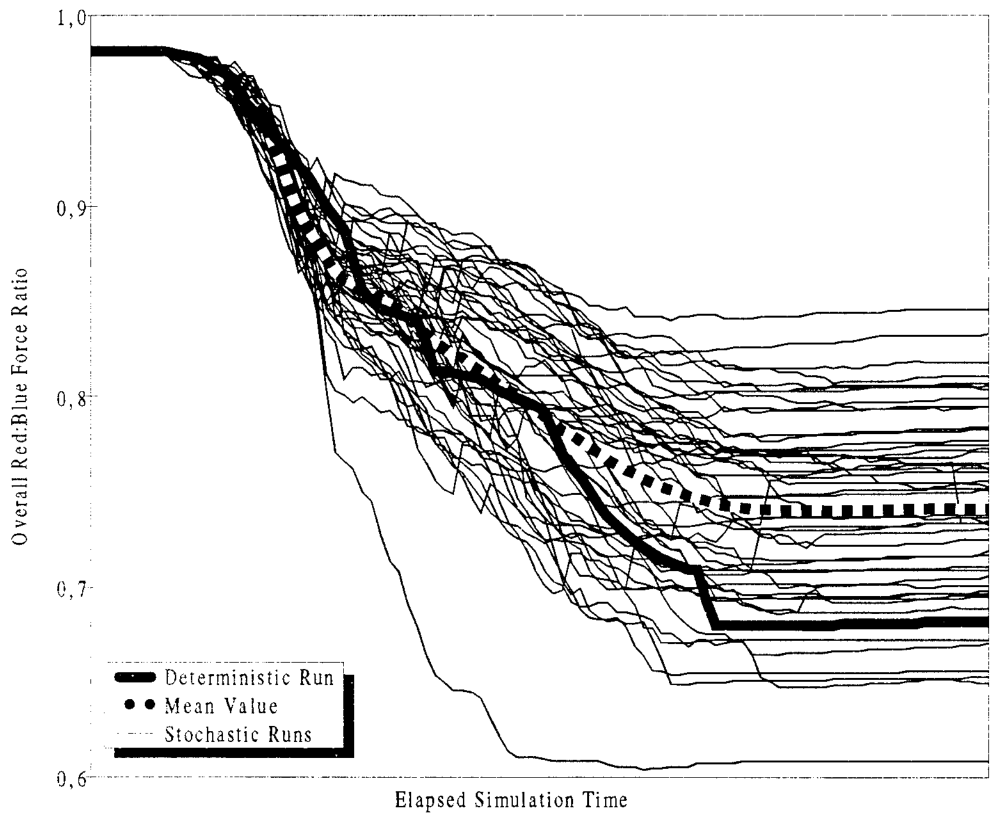

Figure 4.1: Overall Red:Blue Force Ratio

67. Contrary to the overall force ratio, the local force ratio decreases in less than 50% of the 50 experiments, i.e., break-throughs have occurred in a sizeable number of cases. However, for a more accurate assessment of the simulation results, the force ratio by itself is not always a sufficient criterion. This is because the number of Red combat units that accomplish break-throughs may, and did, differ for cases in which the final overall (or local) force ratios were approximately the same[10]. Therefore, an assessment procedure was developed that yields an aggregated *Simulation Value* accounting, in addition to the overall (or local) force ratio, for circumstances at the termination of the experiments that are conducive

- to the exploitation of accomplished break-throughs by the attacker and

[10] The reason for this is that attacking units may break through the defense area without the defending units reaching their breakpoints (at which they are considered as eliminated). Under thinned-out battlefield conditions this will increasingly be the case.

- to completing an imminent break-through.

In other words, the *Simulation Value* reflects, in some proportion, the attrition suffered by both sides throughout the battle on one hand, and the degree to which break-through criteria are satisfied on the other. It provides a scalar measure for complex battle outcomes.

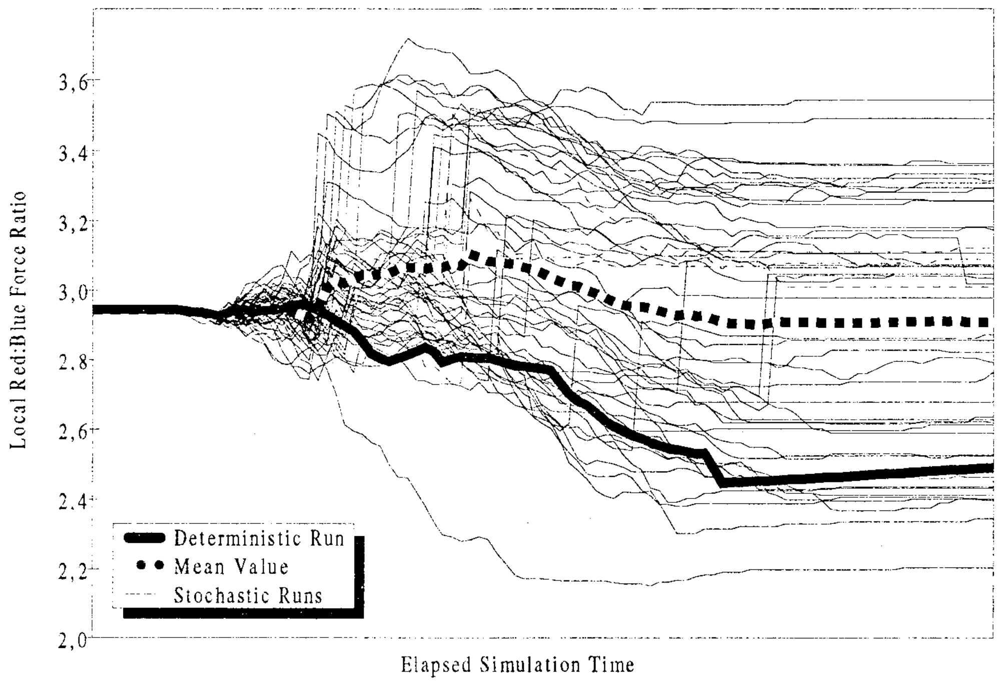

Figure 4.2: Local Red:Blue Force Ratio

4.2 THE SIMULATION VALUE AS A MEASURE OF SUCCESS

68. It is assumed that the success of a break-through may be measured by means of two basic criteria which, depending on the operational objectives, may be given different weights:

a. The attrition suffered by both sides in terms of the change of the attacker:defender combat power ratio. For an attack to be considered successful, the change must reach (or exceed) a given threshold;

b. A successful break-through requires that certain (minimal) values for the remaining strengths are retained by the attacking units reaching the rear of the defender units as well as by the attacking units assigned to flank protection in the break-through sector.

69. Attacker success for the attrition criterion v_a is defined as

$$v_a = \frac{cpr_e}{cpr_i} \cdot \frac{1}{t_{cpr}} \quad \text{and} \quad v_{an} = v_a \cdot n_a$$

with

cpr_e = attacker:defender combat power ratio at the end of the simulation run;
cpr_i = initial attacker:defender combat power ratio;
t_{cpr} = threshold for the change of the attacker:defender combat power ratio (i.e., the attacker:defender combat power ratio at the end of the simulation run cpr_e must be at least t_{cpr} times greater than the initial attacker:defender combat power ratio cpr_i);
n_a = weight assigned to the attrition criterion.

70. Attacker success for the break-through criterion v_{bt} is defined as:

$$v_{bt} = \frac{s}{s_t} \cdot \frac{sr}{sr_t} \quad \text{and} \quad v_{btn} = v_{bt} \cdot n_{bt}$$

with

s = strength of the units reaching the rear of the defender units;
s_t = threshold for the remaining strength of the units reaching the rear of the defender units;
sr = strength of the units assigned to flank protection;
sr_t = threshold for the remaining strength of the units assigned to flank protection;
n_{bt} = weight assigned to the break-through criterion.

71. Both metrics, the weighted as well as the original measurement of success, are positive in case of success, and negative in case of failure. The higher the value the greater the success. The overall success of the break-through operation is calculated in the following manner:

$$v = f \cdot \frac{\alpha \cdot M + (1-\alpha) \cdot m}{\alpha \cdot N + (1-\alpha) \cdot n}$$

with

M	=	v_{btn}, if $v_{btn} \geq v_{an}$, and v_{an} else;
m	=	v_{btn}, if $v_{btn} < v_{an}$, and v_{an} else;
N	=	n_{bt}, if $v_{btn} \geq v_{an}$, and n_a else;
n	=	n_{bt}, if $v_{btn} < v_{an}$, and n_a else;
α	=	Hurwicz-multiplier ($0 \leq \alpha \leq 1$);
f	=	scaling factor.

72. The factor α ($0 \leq \alpha \leq 1$) corresponds the optimism-pessimism index introduced by Hurwicz for reflecting user attitudes with regard to the application of optimistic decision rules in relation to pessimistic ones. For $\alpha = 1$, the user considers the attack to be successful if at least one of the two criteria is satisfied. For $\alpha = 0$, success is measured in terms of whichever of the two criteria values is lower.

73. Except for the experiments discussed in chapter 5.1, it is assumed that an attacking brigade is operational as long as its strength is at least 60% of its initial strength. Thus, the minimal threshold for the break-through criterion is met when the remaining strength is 0.6 of the initial strength of one brigade for both, the attacker forces reaching the rear and the attacker forces assigned to flank protection. Furthermore it is assumed that the combat power ratio should increase by at least 10% in course of the engagement. In this case, the defender is perceived as being too weak to start a counter-attack.

4.3 ESTIMATION OF THE ATTACKER SUCCESS PROBABILITY

74. By means of Fuzzy Set Theory , the crisp simulation values resulting from the simulation experiments are assessed with regard to the probability, or the degree, to which they belong to one of five fuzzy subsets classifying the outcome (see Fig. 4.3) in terms of whether

- the defender wins decisively (*DC*), i.e., the attacker does satisfy neither the attrition nor the break-through criterion ($v_D < v < \infty$),
- the defender wins (*D*), i.e., the attacker satisfies either the attrition or the break-through criterion ($v_U < v < v_{DC}$),
- the battle is undecided (*U*), i.e., the attacker reaches just the minimal threshold for both criteria ($v_A < v < v_D$),
- the attacker wins (*A*), i.e., the attacker reaches the minimal threshold for either one of the two criteria and exceeds it for the other ($v_{AC} < v < v_U$), or

- the attacker wins decisively (*AC*), i.e., the attacker exceeds the minimal threshold for both criteria ($-\infty < v < v_A$).

75. Since the simulation value is calculated by adding weighted values of the attrition and break-through parameters resulting at the end of each simulation run, a poor performance in one criterion can be substituted to some degree by a good performance in the other.

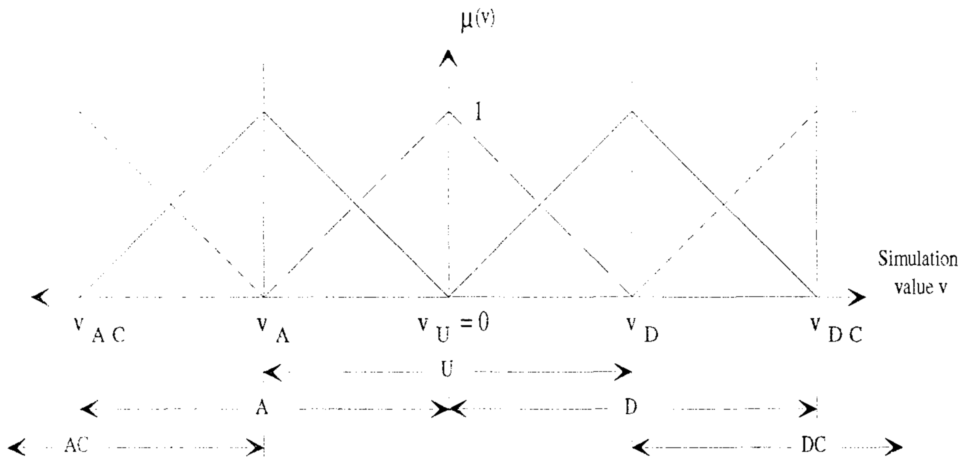

Figure 4.3: Membership Functions of the Fuzzy Subsets

76. The attack success probability estimates are finally obtained from the relative frequency with which the engagement outcomes fall into the just defined fuzzy success classes for the fifty replications of each simulation experiments. They are based on the following success definitions:

Pessimistic Estimate: The simulation value falls into class AC or A, i.e., all undecided battle outcomes are counted as defender success.

Optimistic Estimate: The simulation value falls into class AC, A, or U, i.e., even undecided battle outcomes are perceived as a success, however small, for the attacker.

Average Estimate: Mean of optimistic and pessimistic estimate, in other words, all AC and A events plus half of the U events are considered to represent successful attacks.

CHAPTER 5

SIMULATION EXPERIMENTS

77. There are four series of experiments that have been performed by RSG.18. The first and second series featured the basic scenario as described in chapter 3.2. For the third and fourth, the original basic scenario was modified by removing, from the defending forces, the two brigades adjoining the centre brigade against which the divisional attack is directed. In this manner, fire support from the neighbouring brigades were deactivated. Military experts who had reviewed the results of the first two series considered such an additional fire support as rather exceptional and not being available under normal circumstances when neighbouring brigades would themselves be under attack.

78. Of the total of ca. 17,000 experiments, the first series of 1,100 was to investigate the impact of combat support modules on the outcome of battles. The second series of 10,350 experiments was to analyse the impact of force-to-force and force-to-space ratios given three different attacker movement models. The third series of 2,400 experiments looked into the impact of the structure of units, the fourth of 3,000 experiments into the impact of force-to-force ratios, both under different environmental conditions.

79. The simulation experiments of the RSG.18 study were done within a time span of two years within which the simulation model itself as well as the database and rule sets were constantly reviewed and adapted. Thus, having been generated from different series of experiments throughout that period, the results may not always be directly comparable.

5.1 EXPERIMENTS ON THE IMPACT OF COMBAT SUPPORT

5.1.1 Scenarios

80. In order to assess the differential advantage which the attacker or defender may obtain from various combat support systems, combat support modules (e.g., artillery, attack helicopters, CAS/BAI-sorties) or further weapon systems are added to the forces in the basic scenario. The employment rules remain unchanged.

81. In addition to the basic scenario with (minimal) combat support as described in item 30 (Scenario No. 1), the following scenario variations were examined:

a. Artillery:

- 100% increase in number of weapon systems per battery for the attacker (Scenario No. 2); for the defender (No. 3); for both (No. 4);
- improved (smart) munition effectiveness of artillery systems (900% overall increase of weapon effectiveness against all targets) for the attacker (Scenario No. 5); for the defender (No. 6); for both (No. 7);
- reduced employment range (10 km instead of 25 km) for the attacker (Scenario No. 8); for the defender (No. 9); for both (No. 10);
- reduced employment range and increased munition effectiveness for the attacker (Scenario No. 11); for the defender (No. 12); for both (No. 13).

b. Aircraft:

- five CAS/BAI-missions comprising 15 sorties for the attacker (Scenario No. 14); for the defender (No. 15); for both (No. 16).

c. Combat Helicopters spending 50% of their sortie duration time on battle station:

- 30 *CHEL* employed by the attacker (Scenario No. 17); by the defender (No. 18); by both (No. 19); faced by short range air defense systems (*SRAD*s) of low effectiveness in each case;
- 30 *CHEL* employed by the attacker (Scenario No. 20); by the defender (No. 21); by both (No. 22); faced by short range air defense systems (*SRAD*s) of high effectiveness in each case.

5.1.2 Results

82. Table 5.1 presents the aggregated results of the simulation experiments for each scenario in terms of the relative frequency (in percent) with which the scenario value falls into the five success classes, and in terms of the mean and the standard deviation of the scenario value obtained in each case.

Scenario	AC	A	U	D	DC	Mean Scenario Value	Standard Deviation	
No. 1	13	24	16	36	11	0.0	52.0	Basic Sc.
No. 2	13	24	23	32	8	-3.3	46.2	Artillery Variations
No. 3	5	22	19	41	13	12.1	39.5	
No. 4	8	19	17	46	10	9.3	43.3	
No. 5	12	26	24	35	3	-7.8	46.2	
No. 6	0	0	3	18	79	80.5	6.8	
No. 7	0	0	3	35	62	69.3	10.7	
No. 8	7	24	16	40	13	9.8	45.7	
No. 9	34	26	14	23	3	-33.3	65.1	
No. 10	26	21	18	27	8	-16.1	68.0	
No. 11	13	26	22	31	8	-5.0	47.6	
No. 12	7	22	18	42	11	9.2	43.7	
No. 13	8	22	23	43	4	1.8	51.4	
No. 14	13	26	17	35	9	-3.1	50.9	a/c Variations
No. 15	6	24	23	36	11	8.0	40.7	
No. 16	9	25	19	38	9	4.1	53.0	
No. 17	30	23	24	18	5	-26.2	61.1	Helicopter Variations
No. 18	2	14	20	49	15	23.5	35.7	
No. 19	15	25	22	32	6	-7.6	50.9	
No. 20	14	28	16	32	10	-3.7	57.0	
No. 21	5	30	19	33	13	8.8	47.9	
No. 22	16	27	16	32	9	-6.9	56.0	

Table 5.1: Aggregated results of the simulation experiments with additional combat support

83. As the objective of these experiments is the assessment of stabilizing and destabilizing effects of additional combat support modules, the modal values of the success criteria are calibrated in a manner that the mean scenario value resulting for the basic scenario is set to zero, corresponding to the centre of the class U (uncertain result), whereas the value +100 was assigned to the centre of the class DC (defender wins decisively) and the value -100 to the class AC (attacker wins decisively, see Fig. 4.3). Thus, the mean scenario values obtained for the scenarios with additional combat support indicate the percentage shift to the classes DC (+) or AC (-) caused by the additional combat support. This shift is indicative of the degree to which the additional combat potential is stabilizing (+) or destabilizing (-) relative to the basic scenario.

84. As one would expect, the battle outcome always improves (relative to the base case) in favour of the side that adds combat support systems of whatever kind. In other words, the situation becomes more stable if Blue obtains more combat support, and more instable if Red does. However, the degree of improvement, or deterioration, differs depending on the type of additional combat support, in particular if both sides are reinforced to the same degree.

5.1.2.1 Artillery (Scenarios No. 2-13)

85. As the effectiveness of artillery systems with conventional HE ammunition is relatively modest against protected systems (armour and infantry in foxholes), the degree of their impact is generally small. When adding more howitzers to each battery (Scenarios No. 2 - No. 4), we observe that

- the stabilizing/destabilizing effects from adding additional artillery systems to one side only are relatively small. However, the defender benefits more from additional systems than the attacker;
- if both sides are reinforced to the same degree, the simulation runs indicate a slight improvement for the defending side.

86. The reason why the defender can take more advantage of the increased numbers of artillery systems in this scenario results from the fact that

- the range of the artillery systems is long enough so that the systems of the (not fully engaged) neighbouring brigades can deliver fire support into the main-thrust sector;
- some fraction of the artillery systems of the attacker is always on move. Thus, the availability of artillery is somewhat higher for the defender;

- the percentage of directed fire (with increased effectiveness) is higher for the defender;

- depending on the available preparation time, the vulnerability of defender weapon systems is lower.

87. When the effectiveness of the artillery systems is improved by increasing the single-shot-kill-probability against all targets by a factor of 10 (Scenarios No. 5 - 7), the following results are observed:

- The stabilizing/destabilizing effects from increasing the effectiveness of artillery systems on one side only are obvious. However, the defender benefits far more than the attacker. When only the defender has improved artillery (Scenario No. 6) the battle shifts dramatically toward the category DC and the standard deviation of the aggregated simulation result reaches the lowest value among all simulation experiments;

- this rather dramatic change in favour of the defender also holds, albeit to somewhat less a degree, if both parties have substantially improved artillery systems (Scenario No. 7). Thus, the stabilizing effect of this improvement seems to be robust.

88. The results of the experiments in which the range of the generic artillery systems was reduced from 25 km to 10 km indicate that the artillery batteries of the Blue brigades adjoining the sectors of the engaged brigade in the centre were largely prevented from providing fire support to the latter. Since the Red brigades were able to concentrate all of their artillery fire on the main-thrust sector, the situation was comparable to that of the basic scenario. As a result, the outcomes tend to destabilize the situation.

89. The effects of a reduction in range are, to some degree, compensated by a higher ammunition effectiveness. The results of the respective simulation experiments (Scenarios No. 11 - 13) are similar to those obtained from the basic scenario.

5.1.2.2 Close Air Support and Battlefield Interdiction (Scenarios No. 14-16)

90. Even though aircraft represent highly effective weapon systems, their effect is rather minor. This is because they were limited to only 5 missions (of three sorties each) for the attacker (Scenario No. 14), the defender (Scenario No. 15), and for both parties (Scenario No. 16), in a terrain providing cover and protection for all involved ground units. Thus, further investigations are necessary before even tentative conclusions can be drawn.

5.1.2.3 Combat Helicopters and Short Range Air Defense (Scenarios No. 17-22)

91. As long as the air defense environment is benign (Scenarios No. 17 - 19), unilateral availability of attack helicopters benefits significantly the side having them. If they are in the inventories of both parties, there is a slight tendency for favouring the attacker. In other words, they tend to be destabilizing due to the assumed high effectiveness against a prepared defense. However, when highly effective mobile short range air defense systems protect the combat units (Scenarios No. 20 - 22) the reinforcing effects of the combat helicopters are largely neutralized.. However, a slightly destabilizing tendency is observed in case both sides have the systems.

5.1.2.4 Reservations

92. In considering the effects of artillery, it should be pointed out that the Lanchester coefficients used in the artillery attrition model imply a significantly higher effectiveness when employed by the defender than by the attacker. In contrast, the effectiveness of combat helicopters is assumed to be the same in both roles.

5.2 EXPERIMENTS ON THE IMPACT OF FORCE-TO-FORCE AND FORCE-TO-SPACE RATIOS

5.2.1 Scenarios

93. For all experiments, combat geometry, force deployment and allocation rules remain unchanged. The variations in the initial force-to-force and force-to-space ratios are realized simply by increasing and/or reducing the number of weapon systems in the Blue and/or Red modules. The respective numbers are shown in Tables 5.2 a and 5.2 b.

94. The basic scenario defined in chapter 3.2 is identical to scenario No. 23 for which the force-to-force ratio[11] is equal to 2.94. Variations of this ratio (from 2.06 to 3.81) are the result of varying the number of weapon and support systems in the Red modules (Scenarios No. 19 - 27).

95. Variations in the force-to-space ratio are the result varying first the number of systems in the Blue modules by a certain percentage and, subsequently, in the Red modules so that the force-to-force ratios resulting for the scenarios No. 19 - 27 are maintained. In this

[11] The force-to-force ratio resembles the attacker:defender combat power ratio obtained with the scoring system BAM-G-Kosmos (see chapter 6.2.2, item 88, main body of this report).

manner, the change in force-to-space ratios is identical on both sides. For Scenarios No. 1 - 9, the force-to-space ratios are 50% of the force-to-space ratio in the basic scenario; for Scenarios No. 10 - 19: 70%; for Scenarios No. 19 - 27: identical or 100%; for Scenarios No. 28 - 36: 200%; for Scenarios No. 37 - 45: 300%.

96. In order to test the sensitivity of the stabilizing effects of artillery to the force-to-space ratio, the experiments for the scenarios No. 1 - 45 are repeated without artillery support. In addition, the effects of attacker movement and behaviour are tested by repeating the experiments with different movement models.

	Blue Modules						Red Modules					
	TkBn (1)		MechInfBn (2)		MoInfBn (1)	AABty (3)	TkBn (3)		MechInfBn (9)		AABty (9)	Local Force
Scen.	MMBT	SRAD	AFV	MIT	MIT	AHow	MMBT	SRAD	AFV	MIT	AHow	Ratio
No. 1	20	2	15	30	50	5	14	1	10	21	3	2.02
No. 2	20	2	15	30	50	5	17	2	12	25	4	2.46
No. 3	20	2	15	30	50	5	18	2	14	27	5	2.67
No. 4	20	2	15	30	50	5	19	2	14	29	5	2.80
No. 5	20	2	15	30	50	5	20	2	15	30	5	2.94
No. 6	20	2	15	30	50	5	21	2	16	31	5	3.07
No. 7	20	2	15	30	50	5	22	2	16	33	5	3.20
No. 8	20	2	15	30	50	5	23	2	18	35	6	3.41
No. 9	20	2	15	30	50	5	26	3	20	39	7	3.85
No. 10	30	3	23	45	75	8	21	2	16	31	6	2.04
No. 11	30	3	23	45	75	8	25	2	19	37	7	2.42
No. 12	30	3	23	45	75	8	27	3	21	41	7	2.67
No. 13	30	3	23	45	75	8	29	3	22	43	8	2.82
No. 14	30	3	23	45	75	8	30	3	23	45	8	2.94
No. 15	30	3	23	45	75	8	31	3	24	47	8	3.05
No. 16	30	3	23	45	75	8	33	3	25	49	9	3.20
No. 17	30	3	23	45	75	8	35	4	27	53	9	3.45
No. 18	30	3	23	45	75	8	39	4	30	59	10	3.83
No. 19	40	4	30	60	100	10	28	3	21	42	7	2.06
No. 20	40	4	30	60	100	10	33	3	25	50	8	2.43
No. 21	40	4	30	60	100	10	37	4	27	55	9	2.70
No. 22	40	4	30	60	100	10	39	4	29	58	10	2.85
No. 23	40	4	30	60	100	10	40	4	30	60	10	2.94
No. 24	40	4	30	60	100	10	41	4	31	62	10	3.02
No. 25	40	4	30	60	100	10	43	4	33	65	11	3.17
No. 26	40	4	30	60	100	10	47	5	35	70	12	3.44
No. 27	40	4	30	60	100	10	52	5	39	78	13	3.81

Table 5.2 a: Equipment of Blue and Red Modules

	Blue Modules						Red Modules					
	TkBn (1)		MechInfBn (2)		MoInfBn (1)	AABty (3)	TkBn (3)		MechInfBn (9)		AABty (9)	Local Force
Scen.	MMBT	SRAD	AFV	MIT	MIT	AHow	MMBT	SRAD	AFV	MIT	AHow	Ratio
No. 28	80	8	60	120	200	20	56	6	42	83	14	2.05
No. 29	80	8	60	120	200	20	66	7	50	100	17	2.44
No. 30	80	8	60	120	200	20	73	7	55	110	18	2.68
No. 31	80	8	60	120	200	20	77	8	58	116	19	2.83
No. 32	80	8	60	120	200	20	80	8	60	120	20	2.94
No. 33	80	8	60	120	200	20	83	8	62	124	21	3.04
No. 34	80	8	60	120	200	20	87	9	65	130	22	3.19
No. 35	80	8	60	120	200	20	94	9	70	140	23	3.43
No. 36	80	8	60	120	200	20	104	10	78	157	26	3.82
No. 37	120	12	90	180	300	30	83	8	62	125	21	2.03
No. 38	120	12	90	180	300	30	100	10	75	149	25	2.44
No. 39	120	12	90	180	300	30	110	11	82	165	27	2.69
No. 40	120	12	90	180	300	30	116	12	87	174	29	2.84
No. 41	120	12	90	180	300	30	120	12	90	180	30	2.94
No. 42	120	12	90	180	300	30	124	12	93	186	31	3.03
No. 43	120	12	90	180	300	30	130	13	98	195	33	3.18
No. 44	120	12	90	180	300	30	140	14	105	211	35	3.43
No. 45	120	12	90	180	300	30	157	16	118	235	39	3.84

Table 5.2 b: Equipment of Blue and Red Modules (cont'd)

5.2.2 Results

97. The results are presented in terms of the average estimate of the attacker success probability ASP, or break-through probability (see chapter 4.3), as a function of local initial force-to-force ratio (IFR) for the different force-to-space ratios. Fig. 5.1 and 5.2 show the results with and without artillery when the attacker's movement velocity is loss-oriented[12], Fig. 5.3 and 5.4 when the attacker velocity is reduced to a constant value of 2 km/h, and Fig. 5.5 when the attacker follows a stop-and-go movement doctrine.

[12] In that case, the maximum speed is 10 km/h and the avarage speed resulting from loss-induced reductions is about 5 km/h.

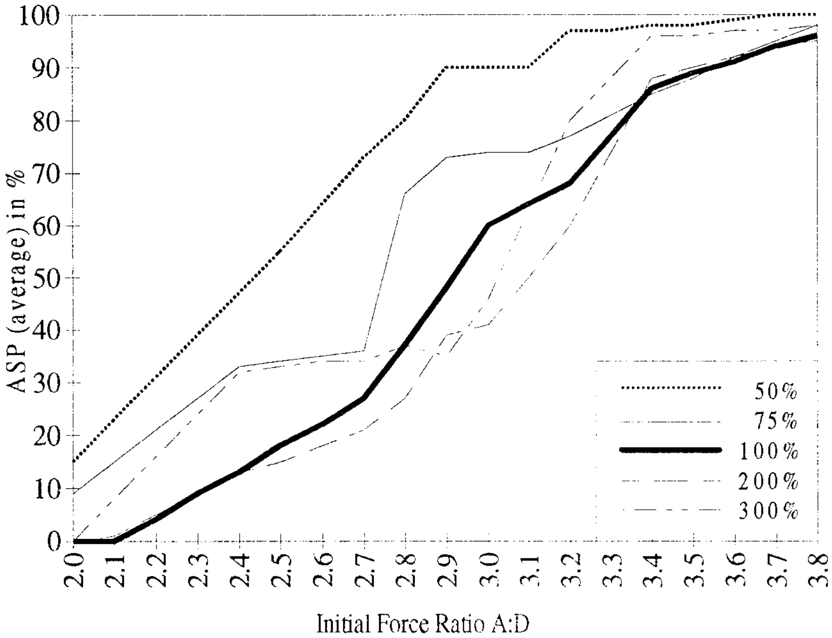

Figure 5.1: ASP over IFR with Artillery (loss-oriented movement model)

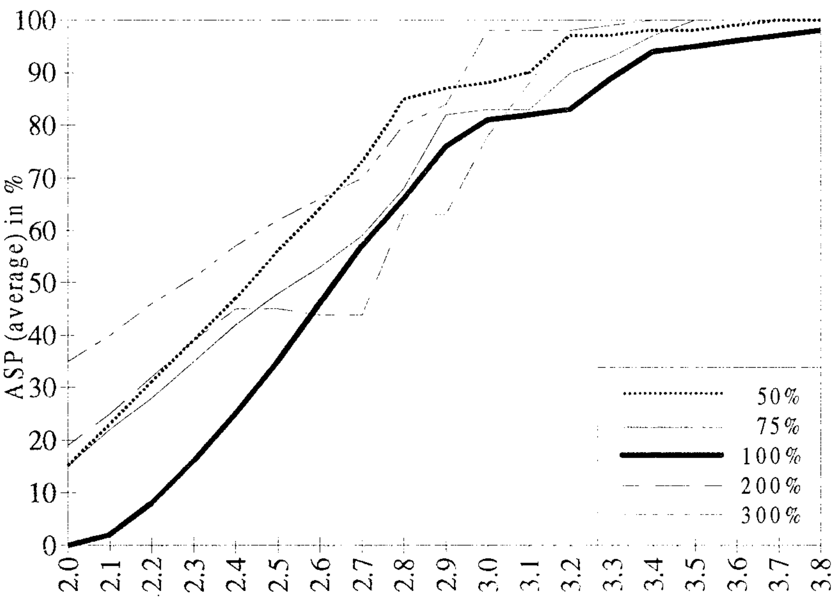

Figure 5.2: ASP over IFR without Artillery (loss-oriented movement model)

98. Fig. 5.1 suggests that lower force-to-space ratios, or thinned-out battlefield conditions, are favourable to the attacker. For example, the so-called break-even force-ratio (at

a 50% break-through probability) shifts from 2.91 in the basic scenario to 2.75 and 2.45 when the force-to-space ratio is 75% and 50% of that in the basic scenario. However, the improvement for the defender is only moderate if the force-to-space ratios are increased beyond the basic scenario's ratio. These effects appear to be quite plausible since operations at lower force densities should be relatively more demanding for the defender than for the attacker, and the attacker may increasingly be able to simply bypass the defender forces in many cases.

99. Similar effects are revealed by Fig. 5.2. However, the curves tend to shift to the left indicating that the attacker benefits from the lack of artillery on both sides. This confirms our previous conclusion in chapter 5.1 on the stabilizing effects of artillery. However, at lower force-to-space ratios these stabilizing effects are reduced. This is not surprising since the effectiveness of an area weapon like artillery with conventional HE-munition decreases as the target density becomes lower.

100. Fig. 5.1 and 5.2 also show that especially at low initial force ratios both, low and high force-to-space ratios are favourable to the attacker. In addition to a great many other factors (such as the degree of artillery support, the number of combat-active weapons, breakpoint assumptions, command and control, etc.), an important cause of this effect may be the attack velocity or, more precisely, the modelling assumptions about the attacker's velocity under fire.

101. Thus, the simulation experiments were repeated with a new movement model that reduces the velocity of an attacking combat battalion to a constant velocity of 2 km/h. The results are shown in Fig. 5.3 and 5.4. The comparison of Fig. 5.1 and 5.3, and of Fig. 5.2 and 5.4, suggests that a reduced attack velocity (in the experiments from on average of 5 km/h to a constant velocity of 2 km/h) tends to have a stabilizing effect, because

- on average, the battles and fire fights between combat modules last longer and, therefore, the defender profits relatively more from the defense advantage existing in the scenarios;

- the defender has more time to deploy his reserves for timely counter-concentrations and to take advantage of the stabilizing effects of artillery systems.

102. It is for similar reasons that the previous observations about the effects of thinned-out battle field conditions are reversed. Fig. 5.3 and 5.4 indicate that a low force-to-space ratio tends to favour the defender when the attacker velocity is low.

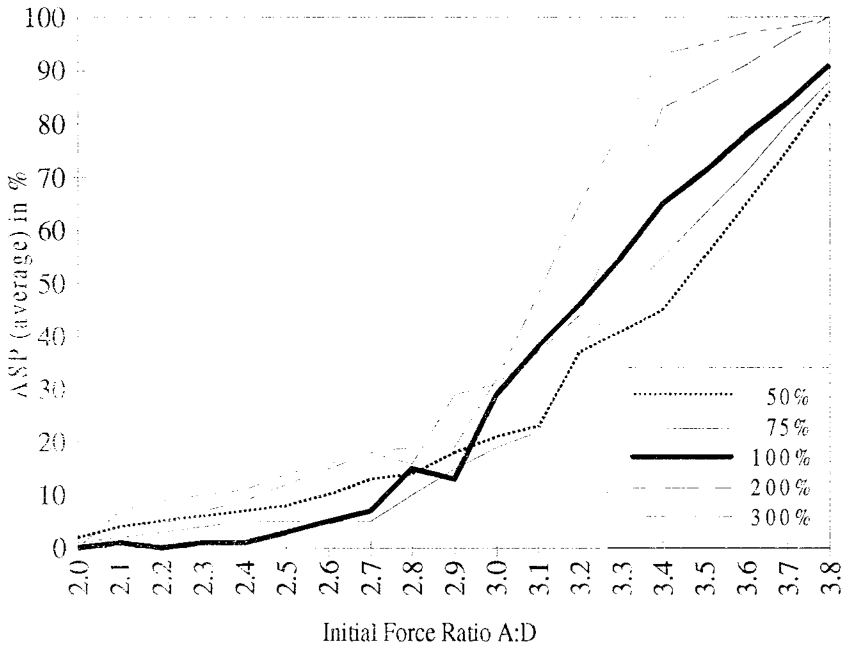

Figure 5.3: ASP over IFR with Artillery and reduced attack velocity (2 km/h)

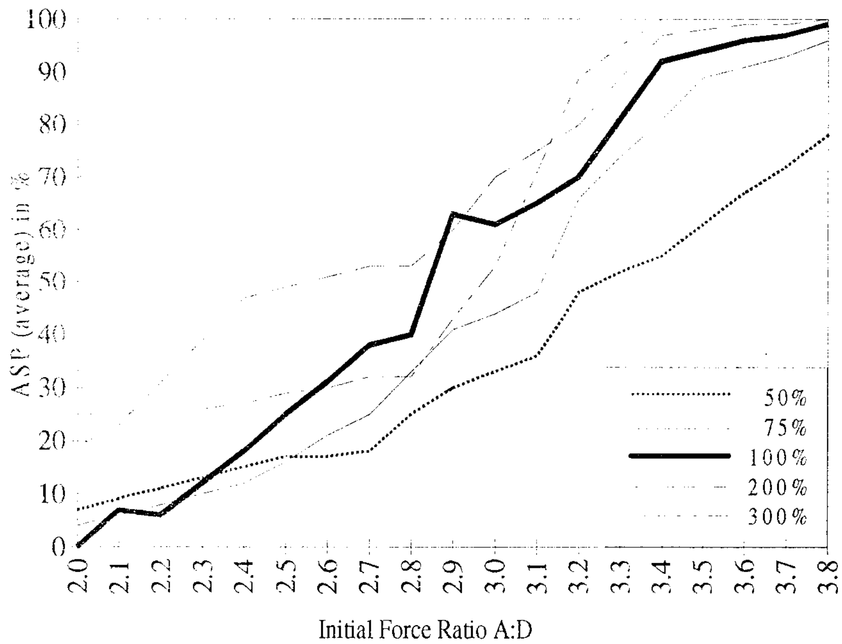

Figure 5.4: ASP over IFR without Artillery and with reduced attack velocity (2 km/h)

103. In order to confirm the findings about the stabilizing effect of a reduced attack velocity, a series of simulation experiments were performed using a stop-and-go movement model. Accordingly, the attacker's unopposed velocity of 10 km/h goes down to zero when engaged in battle with enemy combat modules. The results shown in Fig. 5.5 strongly support the findings. As a rule, high attack velocities favour the party that suffers the higher attrition per unit of time (attacker), low attack velocities (in particular stop-and-go tactics) favour the other side (defender).

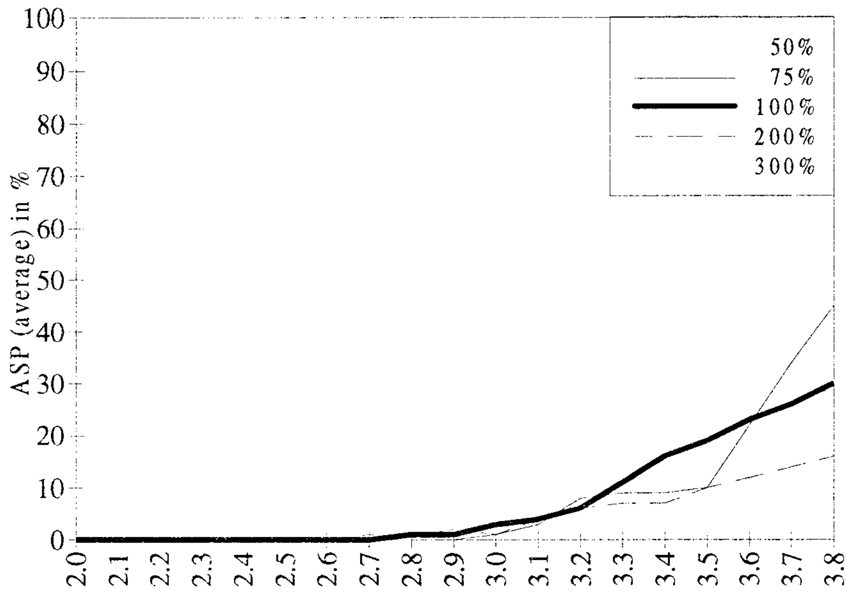

Figure 5.5: ASP over IFR with Artillery and Stop-and-Go movement model

104. With due regard to structural variances that undoubtedly occur in simulation experiments, and with a view to a less than optimal employment of reserves and combat support modules in KOSMOS (by using a single-step optimization process), the curves presented in Fig. 5.1 - 5.5 suggest that break-through probability functions are indeed monotonous.

5.3 EXPERIMENTS ON THE IMPACT OF FORCE STRUCTURES UNDER DIFFERENT SITUATIONAL CONDITIONS

5.3.1 Scenarios

105. For the third series of experiments, the original basic scenario was modified to feature reinforced brigades and divisions as outlined in Fig. 3.5 - 3.9, and to not permit the defending brigade in the main-thrust sector the benefit of additional fire support from neighbouring brigades (see also chapter 3.2).

106. The initial deployment schemes for the three types of defending brigades are shown in Fig. 5.6, 5.7 and 5.8. The three front line battalions are in defense positions at the FEBA. The artillery batteries or the mortar companies are attached and employed as described in section 3.4.3. Each of the defending brigades has two combat modules as reserves. Their employment is explained in section 3.4.2.

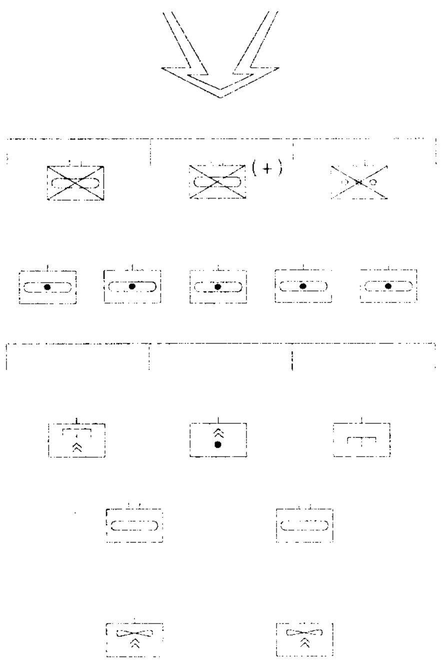

Figure 5.6: Combat Organization of a Defending *MechInfBde I (+)* (M1)

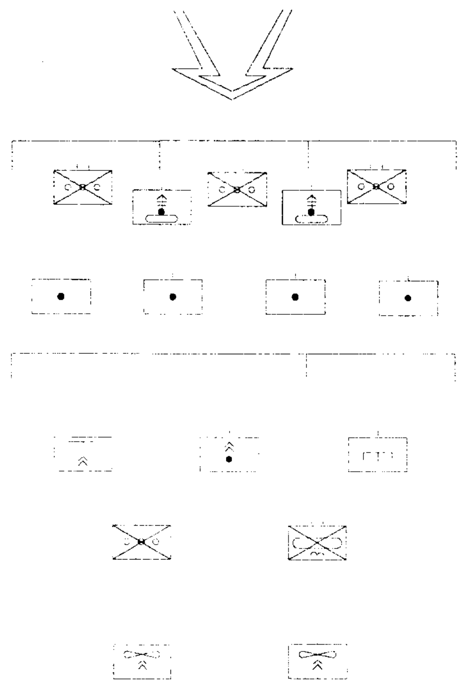

Figure 5.7: Combat Organization of a Defending *MechInfBde II (+)* (M2)

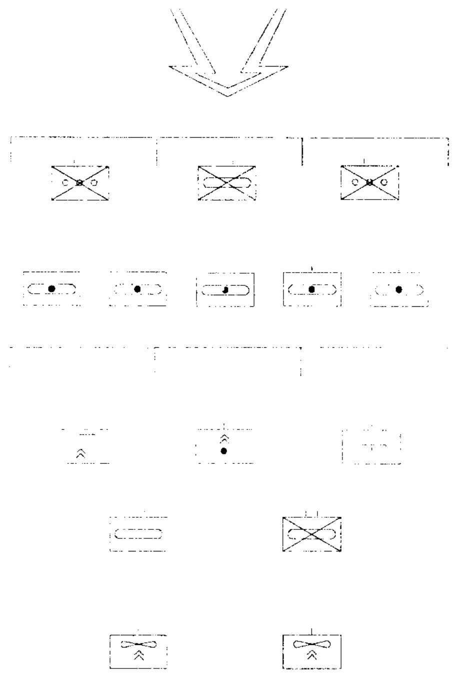

Figure 5.8: Combat Organization of a Defending *MechInfBde III (+)* (M3)

107. The initial deployment schemes for the attacking divisions are shown in Fig. 5.9 and 5.10. Each division comprises three brigades and additional division troops. The

116. The conditions for the experiments include

- three terrain types:
  - **O**: open (favourable to tanks);
  - **M**: mixed (favourable to mechanized infantry);
  - **R**: rough (favourable to infantry);
- two visibility conditions:
  - **P**: poor (visibility range ≤ 500 m);
  - **G**: good (visibility range ≤ 5000 m);
- three degrees of defense preparation:
  - **P**: prepared defense (all systems in field fortifications);
  - **D**: deliberate defense (approximately 50% preparation);
  - **U**: unprepared (no preparation at all).

5.4.2 Results

117. The tables 5.4 a and 5.4 b presenting the results are organized in the same manner as tables 5.3 a and 5.3 b in the previous chapter 5.3. However, the scenario code used there is modified by replacing the unit identifiers by the IS-code (see items 109 and 115).

118. The numbers confirm the observations made in the previous chapter. The dominant influence of defense preparation is revealed when comparing the results of the scenarios OGP, OGD, and OGU. In the latter case, only at an initial force-to-force ratio of approximately 2:1 there is a chance of 26% at best for the unprepared (U) tank-heavy defense (*MechInfBde I (+)*) to prevail in open terrain (O) when visibility is good (G). For higher force-to-force ratios the attacker break-through is certain under these conditions.

119. In case of a prepared defense (P), the influence of terrain is negligible except in open terrain and when visibility is good. In case of a deliberate defense (D), the impact of terrain and visibility is somewhat more marked, terrain being the more influential one of the two.